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McINTIRE-STENNIS COOPERATIVE FORESTRY RESEARCH PROGRAM

COOPERATIVE STATE RESEARCH SERVICE U.S. DEPARTMENT OF AGRICULTURE

The printing costs for this report were borne by the Association of State College and University Forestry Research Organizations.

The McIntire-Stennis program has grown to the point that each research project cannot be abstracted. In this year's report, results are presented for projects typical of subject-matter divisions, followed by lists of all other active projects and recent publications. The 1967 report was compiled by the Cooperative State Research Service directly from progress reports submitted by the principal investigator of each project.

Additional copies may be obtained by request to: Division of Information, Office of Management Services, U.S. Department of Agriculture, Washington, D.C. 20250

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April 1968

FORESTRY RESEARCH PROGRESS IN 1967

McIntire-Stennis Cooperative Forestry Research Program

Introduction

Nineteen-sixty-seven marked the fourth year of research under the McIntire-Stennis Cooperative Federal-State Forestry Research Program. Progress is depicted in this year's report* by selected research examples representing about one-fourth of the total program underway at the 60 cooperating institutions. One or more examples are included for each institution and for each of 18 separate categories of research. In addition, the examples are supplemented by a complete listing of all other projects and resulting publications within each research category, thereby presenting all such relevant information in one place in the report.

More than 500 senior scientists and 408 graduate students were active participants in the 435 research projects comprising the program in 1967. There were a total of 192 publications--about the same as last year. A breakdown of the number of projects, graduate students and publications is shown in the table appearing on the inside of the back cover.

THE MCINTIRE-STENNIS PROGRAM ADVISORY GROUPS

The McIntire-Stennis Act is unique among research authorizations administered by the United States Department of Agriculture in that it establishes specific advisory groups to serve the program. This brings to the program's development the valuable counsel and experienced background of State and National leaders in forestry. They serve on the Cooperative Forestry Research Advisory Committee (Fig. 1) and the Cooperative Forestry Research Advisory Board (Fig. 2), which meet annually in both joint and separate sessions.

The Cooperative Forestry Research Advisory Committee provides advice and guidance to the Secretary of Agriculture from all groups directly concerned with the development of this Cooperative Forestry Research Program. Half of the members of the 14-man committee are representatives of the country's forest industries and half are representatives of Federal and State agencies concerned with developing and utilizing the Nation's forest resources. Assistant Secretary of Agriculture George L. Mehren is Chairman. Dr. T. C. Byerly, Administrator of CSRS, serves as Vice-Chairman and Mr. George F. Burks, Assistant Administrator for Cooperative Forestry Research, is Executive Secretary.

The Cooperative Forestry Research Advisory Board members are heads of forestry schools and are elected by vote of the participating forestry institutions. Six are regional representatives and the seventh is a member-at-large. The Board's primary function is to recommend to

*Compiled by William H. Cummings from reports received from participating institutions.



Figure 1. Members of the Cooperative Forestry Research Advisory Committee and representatives of the U.S. Department of Agriculture. SEATED: L to R, Mr. Paul M. Dunn, Vice President, Retired, in Charge of Timberlands, St. Regis Paper Co.; Director H. Edward Ruark, Georgia Forest Research Council; Dr. T. C. Byerly, Administrator, Cooperative State Research Service, USDA; Dr. George L. Mehren, Assistant Secretary, USDA; Mr. George F. Burks, Assistant Administrator, Cooperative Forestry Research, CSRS; Dr. M. B. Dickerman, Associate Deputy Director of Forest Research, representing Dr. George M. Jemison, Deputy Director of Forestry Research, U.S. Forest Service; Mr. Frederick H. Claridge, North Carolina State Forester, Retired; and Director H. E. Woodward, Colorado Department of Game, Fish and Parks. STANDING: L to R, Dr. Roland R. Renne, Director, Office of Water Resources Research, U.S. Department of Interior; Mr. William M. Beaty, General Manager, Shasta Forests Company, Redding, California; Mr. E. V. Zumwalt, Assistant Director, Resource Management, Bureau of Land Management, U.S. Department of Interior; Director George F. Dow, Agricultural Experiment Station, Orono, Maine; and Mr. Thomas A. DeWeese, Mississippi Manager, Weyerhaeuser Company. Absent were Mr. Arthur W. Nelson, Jr., Vice President, Woodlands Division, Champion Papers, Inc., Hamilton, Ohio; Mr. Clarence W. Richen, Vice President, Northwest Timber Operations, Crown Zellerbach Corporation, Portland, Oregon; and Mr. John B. Veach, President, Hardwood Corporation of America, Asheville, North Carolina.



Figure 2. Members of the Cooperative Forestry Research Advisory Board and representatives of the Cooperative State Research Service, USDA. SEATED: L to R, Director Donald P. Duncan, School of Forestry, University of Missouri; Dean Ernest W. Wohletz, College of Forestry, Wildlife and Range Sciences, University of Idaho; Dr. T. C. Byerly, Administrator, Cooperative State Research Service, USDA; Director Albert P. Nutting, Advisory Board Chairman, School of Forestry, University of Maine; Professor Wilbur B. DeVall, Head, Department of Forestry, Auburn University; Assistant Dean Rudolph M. Kallander, School of Forestry, Oregon State University. STANDING: L to R, Director Frank H. Kaufert, School of Forestry, University of Minnesota; Dr. Philip N. Joranson, Agricultural Administrator, Cooperative Forestry Research, CSRS; Mr. William H. Cummings, Principal Forester, CSRS; Mr. George F. Burks, Assistant Administrator, Cooperative Forestry Research, CSRS; and Dean Richard J. Preston, School of Forest Resources, North Carolina State University, Raleigh.

the Secretary of Agriculture how the Federal funds should be allocated among the States, and this it does in consultation with the Advisory Committee. CSRS also counsels with the Board from time to time on details of policy and procedure.

The members of the Board elect their Chairman. Dr. T. C. Byerly, Administrator of CSRS, is Executive Secretary. The Chairman of the Board has the important responsibility of nominating to the Secretary of Agriculture, a forester to represent forestry research at all institutions participating in the McIntire-Stennis program and in the Hatch program on the Department's very important Agricultural Research Planning Committee. Ordinarily, this person is the current President of the Association of State College and University Forestry Research Organizations serving a two-year term.

The Advisory Committee and Advisory Board held their first two joint meetings in Washington, D.C., in 1964 and 1965. In 1966, they met at the University of Georgia, at Athens and in 1967, at the University of Minnesota.

Forest Biology

The area of forest biology provides a broad but definite grouping that embraces several kindred fields of science. Currently these are designated as Soils, Physiology, Ecology, and Genetics--with the understood prefix of "forest" or "tree" for each term. Of course, the elements of forest biology could be extended beyond these four. Actually a wide diversity of scientific disciplines is involved. This depends on knowledge, skills and experience of scientists conducting the research. The forest biology research effort makes indispensable contribution to sound groundwork through the entire spectrum of forestry research, forestry education, and forestry practice. Accordingly, it is gratifying to note the initial emphasis and growing strength of forest biology research in the McIntire-Stennis program.

SOILS

University of
WASHINGTON 1.

Effect of nitrogen on growth of Douglas-fir.

Stanley P. Gessel

Research on the nutrition of West Coast forest tree species began in 1949. Greenhouse, soils, and field trials established that forest trees in natural stands have mineral nutrient demands not supplied by the soil and forest ecosystem in which they are growing. (Figure 3) Following initial results that featured Douglas-fir response to nitrogen, 350 field plots were eventually established. Nitrogen has been the principal element, applied at rates from 50 to over 1,700 pounds per acre. Response of Douglas-fir growth varies according to the amount of nitrogen applied up to 300 pounds per acre; above this the rate of increase is less. In addition to height and diameter growth, volume of stands and total foliage weight increase significantly: the stand competition changes to hasten suppression of lower crown class trees.

Response to nitrogen treatments on 154 plots of Douglas-fir were averaged by site index: poor at 80-foot, and medium at 140-foot height in 100 years. The curve for site index 140 showed the greatest response for the first hundred-weight of nitrogen applied. Here the 295 cubic-foot volume growth per acre per year average untreated and increased 60 cubic feet to give the total of 355 cubic feet. Beyond the 3 hundred-weight

application of nitrogen, the added volume growth per hundredweight diminished to 5 cubic feet per acre per year, or less than one tenth the response to the first 100 pounds of nitrogen applied.

Currently, diagnostic techniques are under study for prediction of response of Douglas-fir to nitrogen application from foliar and soil analysis, as well as tree condition. Attention concentrates on variation in nitrogen content within and between individual trees in restricted environments to develop sampling standards for effective diagnostic procedures.

University of
HAWAII 139

Fertilization and culture of Hawaii tree crops.

Y. N. Tamimi

Reforestation in Hawaii involves various types of soils and climates on the islands chain. Thus, temperate zone tree species can be grown at high elevations; sub-tropical and tropical species thrive at lower elevations. On evaluating the growth response of some of these species to fertilization, results since experiments were initiated 2½ years ago show phenomenal growth rate of tropical species with fertilization.

The Waiakea Experimental Farm outside Hilo, is on recent lava flow with some soil material admixed with rock; rainfall is from

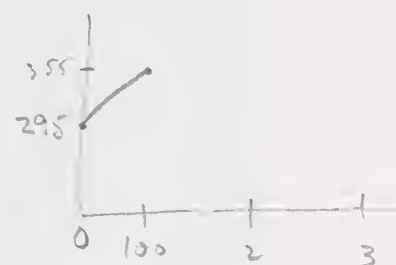
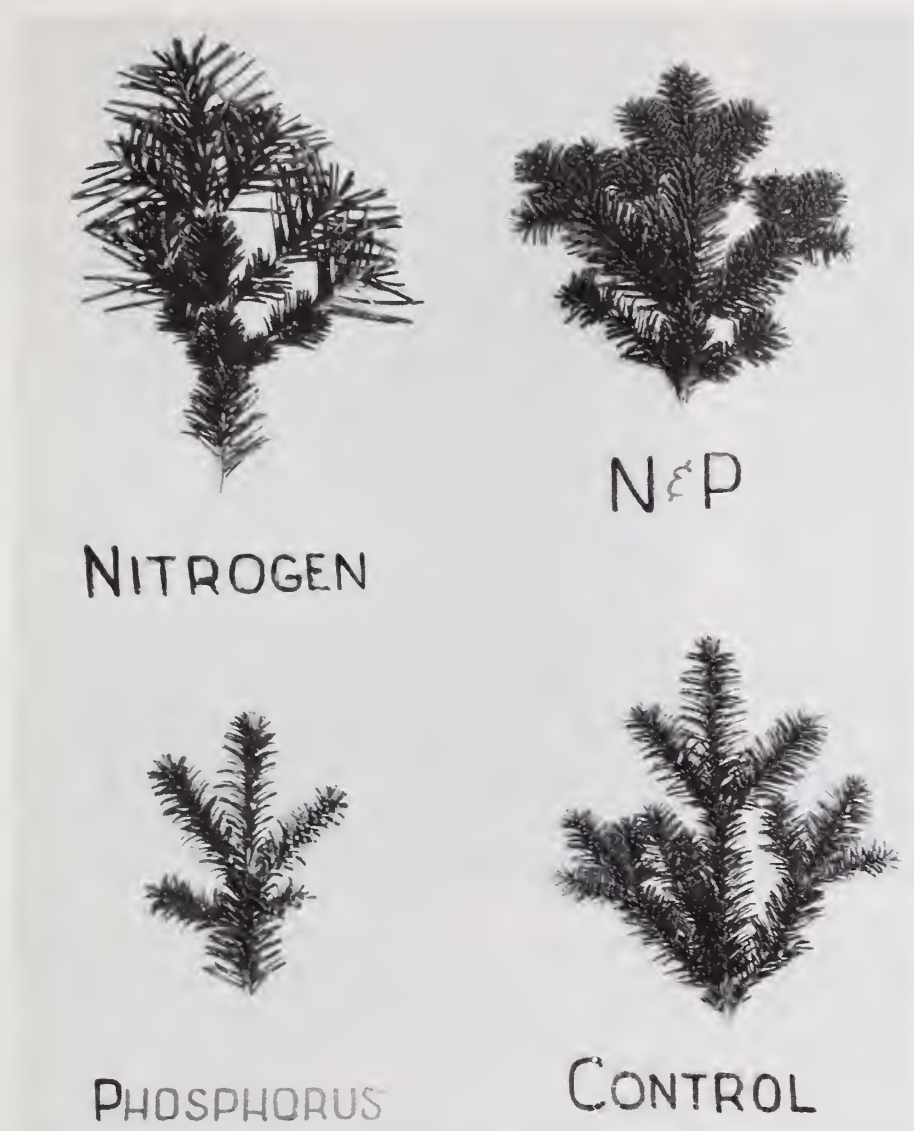


Figure 3. Typical response of Douglas-fir foliage to fertilizer: Nitrogen increased needle size in current, outer growth. University of Washington 11.

150-200 inches per year. On this site, Australian redcedar, a hardwood of the mahogany family with very desirable qualities, grew in $2\frac{1}{2}$ years to an average height of 33 feet and DBH of 4 inches fertilized with nitrogen, phosphorus, potassium, in pounds per acre of 200N-400P-200K as compared to 13 feet height and 1.5 inches DBH for the unfertilized plots (Fig. 4). Another introduced species, saligna eucalyptus, at 2-year age, measured 38 feet in height and 4 inches in DBH when fertilized with 100N-400P-200K. Slash pine had a relatively slow growth rate in the first year at this site: unfertilized trees averaged 1.9 feet in height while the 100N-400P-200K fertilized plots averaged 5.2 feet. Rate of growth of slash pine on this site as compared to that of tropical species, rules this species out as a timber tree for similar areas. Queensland-maple (*Flindersia brayleyana*), a recently introduced species, appears promising.

The unfertilized plots, $1\frac{1}{2}$ years old, achieved a height of 5.4 feet while the 200N-600P-200K fertilized plots averaged 10 feet in height.

Another experimental site, the Hamakua Experimental Farm, has soil classified as Latosolic Brown Forest, developed from volcanic ash; elevation is about 2400 feet; the annual rainfall range is 60-80 inches; and the native ohia is the major tree. Here the above species responded well to fertilizing; however, slash pine and Mexican ash, at $1\frac{1}{2}$ years old did not respond. Other timer species under investigation are monkey pod, Nepal alder, gold tree, and Australian black wood. Windbreaks are very essential in certain windy areas of Hawaii. Accordingly, ten windbreak species have been established to evaluate rates and combinations of N-P-K on their rates and habits of growth in the Waimea area.



Figure 4. Australian redcedar, a desirable hardwood of the mahogany family, on a site of broken-lava with up to 200-inch rainfall grew in $2\frac{1}{2}$ years to average 33-foot height and 4-inch DBH in response to heavy dressing of complete NPK fertilizer, *on right*, as compared with untreated 13-foot height and 1.5-inch DBH, *on left*. University of Hawaii 139.

University of
TENNESSEE 2.

Effects of fertilization and irrigation on tree growth.
Edward R. Buckner

A natural yellow-poplar stand 30 to 55 years old on a south slope in the ridge and valley region of East Tennessee is the site of an experiment to test the influence of fertilizer, and irrigation on diameter and height growth of trees growing on both the dry upper slope position and near the foot of the slope where moisture is more abundant. After three growing seasons, fertilizer continues to stimulate yellow-poplar growth significantly both in diameter and height--especially the diameter growth on lower slope. The response was consistent for the three seasons on the upper slope; however, on the lower slope, response was greatest the second season but lacking this past season. Irrigation increased both height growth and diameter growth, and was most effective on the upper slope. The com-

bined treatment of irrigation plus fertilization increased height growth; diameter growth more than doubled that of control trees. This treatment was most effective on the upper slope.

Yellow-poplar, sweetgum, northern red oak and loblolly pine seedlings that were subjected to the same treatments as the natural yellow-poplar stand have completed their third growing season in the field. Average height growth of all species except loblolly pine was better on the upper slope, forest soil than on the lower slope, old field. Fertilizer placed in the planting hole gave growth response that was greatest in yellow-poplar, followed by sweetgum, loblolly pine, and northern red oak; fertilizer was most effective on the upper slope position. Irrigation on the upper slope gave response of the four species in the same order as their response to fertilizer. Irrigation plus fertilization increased the height of all species on the upper slope as

follows: yellow-poplar growth more than doubled, next, northern red oak, and loblolly pine. On the lower old-field slope, fertilizer and irrigation treatments were less effective, ranging from limited stimulation of growth in yellow-poplar and sweetgum to depression of growth in loblolly pine and northern red oak.

By the end of the third year, there appeared to be a consistent pattern in the results from four treatments. Combined application of fertilizer and irrigation appeared best, single application of fertilizer or irrigation intermediate, and untreated check the least. In growth response of four species, yellow-poplar was best, sweetgum next, and northern red oak or loblolly pine the least. This study shows that irrigation and fertilizer can stimulate growth of species like yellow-poplar for potential volume increase.

Clemson University
SOUTH CAROLINA 789

Fertilization and irrigation of upland hardwoods.

W. H. Davis McGregor

This research was designed to evaluate the relative importance of moisture stress and mineral nutrient deficiency as factors restricting the growth of upland mixed hardwood-pine stands. The ridge tops and the upper slopes involved are the least productive sites of the Piedmont from the standpoint of commercial timber production. A secondary objective is determination of silvical changes taking place in response to nutrients supplied to the vegetation of these sites.

A dry, narrow, north-south ridge was selected for this research because of available irrigation water in the quantities needed. It was necessary, however, to construct a small dam to impound the water of a stream in a nearby valley. Eight 1/4-acre plots were laid out along the brow of the ridge and eight more closely below the brow of the same ridge on a slightly better site. On each plot all trees over 2-inch DBH have been tagged, measured, and recorded by species; and, on subordinate plots, understory woody plants,

tree reproduction, and herbaceous vegetation are recorded. This exhaustive quantitative inventory will provide the basis for re-measurements to accurately assess treatment effects on vegetation for three or more years.

The irrigation water will be pumped from the pond by a 25-horsepower engine through 4-inch irrigation pipe laid out to four of the ridge-top and four of the off-ridge plots. An impulse-type sprinkler can irrigate each plot with up to 1½ inches of water in 10 hours. Fertilizer will be applied as a sub-treatment to one-half of each of the 16 plots before treatments are activated in spring, 1968.

University of
FLORIDA 1250

Water control for forest production.

Clemens M. Kaufman
R. E. Choate, William L. Pritchett

This research deals with the response of planted pine to major differences in the water table: 18-inches kept uniform, 36-inches kept uniform, and uncontrolled. Slash pine, three growing seasons after planting as 1-0 seedlings, were tallest on the 18-inch water table, and next tallest on the 36-inch, as compared with the uncontrolled water table. Loblolly pine showed even greater differences--growth on 18-inch water table more than doubled that on uncontrolled. Within the study, trees fertilized at the beginning of the second growing season with diammonium phosphate (18-48-0) at a rate of 398 pounds per acre stimulated height growth of both pines at all three water table levels. Tree height increases in terms of unfertilized ranged from 13 percent on the 36-inch water table to 44 percent on the uncontrolled water table--both for loblolly pine. On the 18-inch water table, the fertilized slash pine averaged 9.55 ft. in height and the unfertilized, 7.35 ft.; the loblolly were 8.46 and 6.89 ft., respectively.

On each of 19 areas selected for uniformity of saw palmetto and forest cover, the palmetto was removed from one of two plots. During

the 1967 spring drought of April to mid June, the non-palmetto areas showed no significant advantages in the volume percentages of soil moisture at the surface and the 1-, 2- and 3-foot soil levels. In the less severe drought intervals of May 1966, results had been similar.

In a flatwoods forest area, planting areas have been cleared for a study on the effect of ditching at several levels and drainage of ponds. Arrangements are made to plant slash pine in 1968.

University of
ALASKA 0501

The role of alder in nitrogen nutrition of forests in interior Alaska. Paul E. Heilman

This study dealing with American green alder, a spreading shrub widely distributed in interior Alaska, was terminated during the year. This alder builds up the nitrogen content of soil by fixation; to high levels in pure stands; about 1/3 less as an understory of aspen stands--but still improving the nitrogen status of associated species significantly. A simplified procedure for determining the nutritional status of forest soils was developed.

University of
ALASKA 0502

The effect of sphagnum mosses on forest production and soils of north slopes of interior Alaska.

Paul E. Heilman

This project was terminated during the year with a report on results. Declining availability of nutrients is a primary factor in reducing productivity of forests with advancing succession on north slopes of interior Alaska. The significant drop to deficiency status of N, P, and K in the foliage of black spruce attests to this declining availability in even the early stages of succession. Although invasion of sphagnum signifies further decline in productivity, forest production from the point of view of forest management is virtually nil even before this stage is

reached. However, total productivity in dry weight of organic matter on the sphagnum bogs is substantial.

University of
ALASKA 0503

Properties of forested podzol soils of southeastern Alaska. Paul E. Heilman

The project was terminated during the year with a report. Mineral and organic horizons were determined. Investigation was made of solubility, molecular size distribution, and associated cations in organic horizons. Molecular sieve chromatography was shown to be satisfactory for study of this organic matter. Additional study is needed of the relationship of organic matter in illuvial horizons to stability.

OKLAHOMA
State University 1234

Biological, nutritional and physical properties of the soil affecting Oklahoma tree species.

J. Q. Lynd, T. H. Silker

Studies with soil biological factors influencing growth and development of shortleaf pine were established with a Typic Quartzipsamment. Variables for initial factorial experiments included differential soil steam sterilization with and without mycorrhizal inoculation, allyl alcohol treatment, *Trichoderma viride* inoculations and nitrogen-phosphorus fertilization. Soil fertility and microbiological influence on shortleaf pine growth and root development were determined with nitrogen, phosphorus and potassium treatments combined with sterilization and re-inoculation. Results after losses from hailstorm destruction of greenhouses, indicated: soil sterilization decreased plant height and plant top weights, apparent growth was slightly greater with re-inoculation as compared to check treatments, phosphorus additions increased growth, whereas nitrogen and phosphorus additions decreased yields, and additions of potassium further depressed growth.

OTHER PROJECTS

CALIFORNIA - Humboldt State College 6. *Soil moisture drying curves-management relations.*
Mark Rhea.

CONNECTICUT Agricultural Experiment Station 411. *Phosphorus in lake sediments in forested watershed.*
R. D. Hartner.

CONNECTICUT Agricultural Experiment Station 415. *Waste water renovation potential of forest soils predicted by their chemical and physical properties.*
D. E. Hill, P. E. Waggoner.

University of HAWAII 140. *Forest floors and soils in some introduced and indigenous forests of Hawaii.*
L. D. Swindale.

University of KENTUCKY 194. *Mechanisms involved in differential cation and anion uptake by plant roots and the relationship of differential cation and anion uptake to plant adaptability.*
A. J. Hiatt.

LOUISIANA State University 1276. *Rooting depth of mature southern pine trees as limited by soil characteristics.*
Norwin E. Linnartz.

LOUISIANA Polytechnic Institute 4. *Nuclear methods for determining site index.*
John Kuprionis.

University of MAINE 5002. *Factors affecting growth of commercial forest tree species in Maine.*
Charles E. Schomaker.

University of MONTANA 1101. *The genesis of a brown podzolic soil.*
Thomas J. Nimlos.

NEW YORK - Cornell University 905. *Effects of soil fertility on forest ecology and growth.*

Earl L. Stone.

NORTH CAROLINA State University 4018. *Fertilization and irrigation of seed orchards.*

C. B. Davey.

OHIO State University 1. *Effects of fertilizers on soils and growth of maples and poplars in N.E. Ohio.*

John P. Vimmerstedt.

PENNSYLVANIA State University 1487. *Fertilization of forest stands for timber and wildlife food production.*

W. W. Ward, J. S. Lindzey.

SOUTH DAKOTA State University 452. *Relationships of soil characteristics and vegetation to recent establishment of ponderosa pine in the grassland areas of the Black Hills.*

James T. Nichols.

University of WASHINGTON 17. *Pedological investigation of some of the forest soils of western Washington.*

Fiorenzo C. Ugolini.

WASHINGTON State University 1913. *Forest watershed disturbance by skidding with crawler and rubber-tired tractors.*

Donald R. Satterlund.

PUBLICATIONS

Heilman, Paul E.

1966 *Change in distribution and availability of nitrogen with forest succession on north slopes in interior Alaska.* Ecology 47: 5.

Wiant, M. K.

1967 *A growth-prediction method of measuring stem growth response by mature oaks to forest fertilization.* M.S. Thesis. Pennsylvania State University.

PHYSIOLOGY

University of
ILLINOIS 303

Factors related to the growth and development of forest tree species in central Illinois--with special emphasis on internal moisture balance and photosynthetic-respiratory ratios.

William R. Boggess

Daily rates of photosynthesis and respiration were measured in the field for seedlings of sugar maple, bur oak, red oak, and white oak (Figure 5). The study goal is to assess the physiological reasons for the replacement of the oaks by sugar maple in natural stands where both are present in the canopy. Identical field layouts were established under full canopy shade and in a natural canopy opening. Net photosynthesis started at average light

levels of 49-foot candles (FC) with sugar maple, 61 FC with bur oak, 97 FC with red oak, and 107 FC with white oak. Mid-day light levels under full canopy shade in the experimental area averaged between 80 and 130 FC. As a result, only minimal rates of net photosynthesis were recorded for red oak and white oak under full canopy shade. Sugar maple and bur oak exhibited greater rates of net photosynthesis under the same conditions and are better adapted to growth and survival under a full canopy. Substantially increased rates of net photosynthesis occurred in all species as a result of brief periods of increased insolation, or sun beams through the canopy. Analysis of data will define the magnitude of these differences, and the responses of the four species to release in a natural canopy opening.



Figure 5. Bur oak seedling enclosed in mylar bag used to retain carbon dioxide exchange for field measurements of photosynthesis and respiration. Refrigerated air is supplied to the bag through insulated hoses to control internal air temperature. University of Illinois 303.

Light and internal moisture of beech seedlings.

Boyd W. Post

The objective of the research is to evaluate the environmental factors basic to the development of high quality beech timber. This requires determining rates of apparent photosynthesis and transpiration of beech seedlings under varying levels of light intensity with optimum soil moisture conditions and various levels of internal plant water supply. Results achieved on initial experiments to determine the response of beech to light intensity have differed from those reported for other northern hardwood seedlings. Instead of a steadily rising rate of photosynthetic activity with increase in light intensity, we found that increase in photosynthesis (group average) occurred up to about 3000 foot candles.



Figure 6. Graduate student Barrett Gates seals the American beech seedling into the base of the control chamber. This will control light intensity, temperature, humidity, and carbon dioxide content. Here, the concurrent measurement of the leaf's rates of photosynthesis (or carbon dioxide absorption), and transpiration (or moisture output) will define the seedling's response to environmental conditions. University of Vermont 9.

(Figure 6). At the next higher level a decrease in photosynthetic activity was observed. High rates of photosynthesis were obtained at the next higher intensity and then no appreciable change was noted up to 10,000 foot candles. Since these wild seedlings may have been adapting to the pots and the greenhouse conditions, and thus not responding normally, this experiment will be repeated. Following completion of this light intensity study, the response to internal moisture balance will be examined.

CONNECTICUT

Agricultural Experiment Station 405

Environment and photosynthesis.

Dale N. Moss

Survival of seedlings in woodland shade and their eventual success when an opening appears depends upon the balance of photosynthesis and respiration, first in a shady environment and then in a sunny one. This project, begun in 1964 and concluded in 1967, therefore concerned the metabolism of five species: shade tolerant dogwood and sugar maple, and intolerant quaking aspen, yellow-poplar, and yellow birch. Shade made all leaves thinner and changed size and stomata in some. Tolerant species, although less efficient in photosynthesis in bright light became more efficient than intolerant in dim light. When the plants were grown in the shade, this difference was particularly evident. The advantage is small, however, and occurs only in light dimmer than 300 foot candles.

Respiration, the other side of metabolism, presented a more revealing difference. Dark respiration of intolerant species grown in the shade was one-third greater than that of tolerant species. This could certainly affect both survival in a shady environment, and later success in the sun.

CONNECTICUT

Agricultural Experiment Station 408

Conserving soil moisture by foliar spray of stomata-closing chemical.

Paul E. Waggoner

Since most rainfall is lost from the continent through evaporation from leaf pores or stomata, the possibility of water conservation

through stomatal shrinkage existed. In 1966, a red pine plantation averaging 48-feet in height was sprayed with a stomata-closing chemical which resulted in conserving a significant amount of water.

In the much wetter year of 1967, the treatment was repeated in June, and resulted in conserving more than an inch of loss of moisture through evaporation from the plantation. New instruments revealed that the stomata were in fact shrunk, and the hydration of the shoot increased--indicating moisture retention within the tree. Associated diametral growth of the boles was decreased more in 1967, the second year of treatment, than in the first year. Another treatment, in mid-July 1967, proved less effective than the first treatment in early June. These two years of research experience suggest that moderate changes in stomatal resistance might achieve conservation on the order of an inch of evaporation, and hence rainfall, on a forested watershed.

University
WISCONSIN 1350

Effect of metabolic antitranspirants on internal water balance, growth, and survival of outplanted trees.

Theodore T. Kozlowski

Alkenylsuccinic acids have been reported to act as metabolic antitranspirants which prevent stomatal opening in the light and induce closure of already open stomates of herbaceous plants. These compounds have also been reported to increase permeability of cell membranes of roots of herbaceous plants to water. Because of these considerations, root-dip and leaf spray experiments were conducted on effects of various succinic acids on the water balance and growth of trees.

Root systems of 1-year-old red pine seedlings immersed in solutions of various succinic acids gave no evidence of increased permeability of roots. In an 8-year-old plantation, red pine trees were sprayed in July 1966 with decenylsuccinic acid, DSA, at five molar concentrations of 5/10, 1/10, 1/100, 1/1000, and 1/10,000. Shoot growth

of the red pine trees in 1967 was markedly depressed by the DSA applied.

The effect of the film-type antitranspirant, cetyl alcohol, on water relations of potted, 3-year-old white spruce seedlings was studied in the greenhouse. Two commercial forms of cetyl alcohol were used: Adol 52 and Adol 54 (95 and 70% cetyl alcohol, respectively). Two concentrations, 5 and 10%, of each antitranspirant were applied as sprays. Daily transpiration of all seedlings was determined gravimetrically for 10 days before treatment and (at 48 hr. intervals) for 6 days after treatment. Following application of the cetyl alcohols, daily transportation rates declined markedly compared with untreated control plants. Application of Adol 52 at 5% reduced transpiration to 60% of that in control plants, and, at 10%, Adol 52 reduced transpiration to 30%. Both 5 and 10% of Adol 54 reduced transpiration to 40% of control plants. Soil moisture contents were higher following treatment with cetyl alcohols than in control plants. Some injury caused by Adol 52 may have resulted in the observed decrease in transpiration.

University of
MISSOURI 522

A study of the energy and water balance of forest and range sites.

Gene S. Cox, Wayne L. Decker

The purpose of this study is to evaluate the rate of transfer of moisture and heat between soil-plant-air surfaces (Figure 7). In 1967, upland hardwood stands used about 0.15 inches of water per day from March through October as determined by the water balance method. Daily evapotranspiration rates are similar to those reported for corn and a fescue meadow in the same area. Collection of micrometeorological data is now in its second year. Currently, these data are being analyzed to determine net radiation, latent heat of evapotranspiration, sensible heat transfer, and soil heat flow.

Preliminary analysis of weather information for selected periods in 1966, ranging in length from 11 to 15 days, was used to compute



Conditions above oak crowns are measured with instruments mounted on telescoping tower. This can be readily raised from its minimum of 26 feet to the maximum 72 foot height. Moreover, the entire unit pivots to permit servicing instruments from the ground.



Figure 7. On this Ozark hardwood forest floor, basic measurements for energy balance extend from the familiar Weather Bureau shelter containing maximum-minimum thermometers to the instrument rack operated by graduate student Frank Holt standing to front of tower base. University of Missouri 522.

evapotranspiration both by Penman's, and Thornthwaite's methods. Their indicated respective daily water use rates averaged 0.15, and 0.06 inches; their maximum rates of 0.22, and 0.11 inches occurred in July; their minimum rates were 0.09, and 0.03 inches in November. For comparable periods, the water balance method indicated daily evapotranspiration rates that averaged 0.17 inches and varied from 0.21 inches in July to 0.07 inches in October. Further analyses of comparative evapotranspiration rates are being made to follow up these tentative indications.

Rutgers University
NEW JERSEY 245

A physiological and biochemical study of phase change in plants.
Charles E. Hess

This research deals with the regulation of phase change in plants. It is possible to rejuvenate scions or buds of the mature phase of English ivy by grafting on to juvenile understock. It is also possible to rejuvenate the mature phase with applications of gibberellic acid A_3 . Therefore, phase change in English ivy may be under hormonal control.

Two gibberellin-like substances were found within the tissue of English ivy. Although the biological activity of the substances is similar to that of gibberellic acid A_3 , the substances are chemically different. There are larger quantities of the gibberellin-like substances in the juvenile tissue.

As a working hypothesis, it is suggested that gibberellic acid may cause rejuvenation in English ivy by altering nucleic acid synthesis, by this plant. The rate of synthesis of the nucleic acids appears to be much greater in juvenile tissue; however, separation of the ribonucleic acids into soluble, light and heavy ribosomal and messenger fractions did not reveal differences between the juvenile and mature tissues. It will be necessary to develop techniques for greater resolution of the messenger ribonucleic acid fraction and to study changes in enzyme synthesis in order to substantiate the working hypothesis.

University of
GEORGIA 6

Relation of environment to growth and reproduction of southern forest trees.
Mervin Reines

Observations were reported last year on the phenology of flower and bud development during 1965 and 1966 growing seasons. Supplementary notes on sweetgum are given here. The rapid enlargement of leaves began about two weeks after they emerged from the buds, and leaves matured by mid-May. Long shoots continued to elongate and initiate new leaves throughout the growing season until bud scales were formed by mid-August. The cambium tissue responsible for the production of new bark and wood appeared hydrated and was producing phloem, or inner bark, elements as early as March 30. The major cambial activity of wood formation ceased by mid-August; thus most of the radial growth occurred in a 90-day period. The time of initiation of floral and vegetative growth varied greatly among trees. Both floral and vegetative flushes occurred later in 1966 than in 1965. This is possibly attributable to cooler temperature in 1966 than in 1965 during critical months of February, March and April.

University of
GEORGIA 2

Variation in storage of total carbohydrates as reserve food in roots of pine and hardwood species and its relation to genetic and environmental factors.

L. W. R. Jackson

As reported last year, crown density was the only characteristic of shortleaf pine found significantly correlated with food storage, and variation among clones was not significant.

University of
IDAHO 2

Elongation and activity of roots of coniferous seedlings as determined by radioactive tracers.

Franklin H. Pitkin, Howard Loewenstein

How can we do a more successful job of establishing grand fir plantations in the Inland Empire? Because of rapidly expanded interest

in this species, both for pulpwood and Christmas-tree purposes, we have started research aimed at improving the plantation survival. The field research during the past growing season involved comparisons between two lots of outplanted 2-0 seedlings. One group of grand fir seedlings was treated with solutions. They received first, a 15-minute top soak in a 0.1% maleic hydrazide solution, then, a two-hour root soak in a solution of indolebutyric acid plus indoleacetic acid at 1 and 10 parts per million. The top soak was made to inhibit bud breakage, in the hope that reduced top growth might enhance survival. The root soak was designed to overcome any inhibitory effects of transported maleic hydrazide on root development as well as to possibly stimulate root initiation and growth by the growth-promoting indole-acid hormones. The second group of seedlings served as controls. Root growth was traced by injecting radio-phosphorus in the soil at various depths and lateral distances from individual planted seedlings. This was followed by sampling the seedling foliage at weekly intervals for detection of absorbed nuclear radiation. Presence of radioactivity would indicate that roots were present in a particular injection zone. Soil moisture and other environmental data were collected on each date of foliage sampling.

The summer of 1967 was one of the driest and hottest of the present century in northern Idaho: only a trace of precipitation was measured on the experimental area during July and August. Soil moisture content at both the 3 and 8 inch depths fell to the wilting point by the latter part of July, but remained well above that point through August at the 16- and 24-inch depths. As a consequence of the very droughty conditions, both control and treated plots suffered heavy mortality of about 80 percent. A definite retardation of bud breakage was noted for treated seedlings, so for a longer period during the summer these plants probably had lower transpiration rates than controls. Had there been some recharging of surface soil moisture in July, as is normal in most years, considerable difference in mortality between the two plots might have occurred.

The fact that soil moisture remained ample at lower profile depths proved of no value to survival, and radiotracer information showed why. In contrast to previous work with Douglas-fir and ponderosa pine, the grand fir trees produced little new root growth. Foliar radioactivity was detected only in situations where the isotope had been injected in the soil just one inch from the plant and at either a 3 or 8 inch depth--within the original root zone. This indicates that the hormone treatment did not promote root elongation. Further, the actual amount of radioactivity in the foliage differed little as between treated plants and controls. This suggests that the treatment probably did not increase the absorptive ability of the original root systems of grand fir during this season.

University of
MICHIGAN 1.

Techniques for use of $C^{14}O_2$ to tag current photosynthate in studies of phloem transport in forest trees.
Robert Zahner

Research in this project is concerned with the distribution within red pine trees of sugar from photosynthesis. Carbon-14-labelled photosynthate is traced to its source at all seasons of the year--the primary objective to determine when and how much sugar is incorporated into wood cells in the bole of the tree.

For example, photosynthate is labelled in a number of trees during clear days in October. These trees are then harvested periodically over the following 12 months, some in January, some in April, some in July, and the remainder in October a year later. Upon harvesting, a tree is divided into leaves, branches, main stem, and roots. Each of these tissues is then analyzed to determine what portion of the labelled sugars is currently in various protein, carbohydrate, and lipid products, with emphasis on cellulose in the main stem. The entire processes are repeated for each season of the year, that is, photosynthate is labelled not only in October, but also in winter, spring, and summer.

Results are yielding heretofore unknown information concerning the pathway of photosynthate from its first sugar products, through storage products, through transported products, and finally into wood cellulose. Early results indicate, for example, that lipids (fats) play a large role in storing photosynthate at every season in the roots and bark prior to incorporation into wood.

University of
MICHIGAN 12

Vessel length in angiosperm xylem.

Robert Zahner

This research is concerned with the longitudinal course of water-conducting cells and their vertical distribution in the branches and main stems of such trees as oaks and ashes. The formation of wood in these ring-porous trees has been the subject of much theory since the 1890's, and factual progress has been hampered by lack of basic knowledge concerning the anatomy of wood vessels as they wind their course from leaves through stems to roots.

The study is utilizing a unique method for observing and measuring the lengths of individual vessels and the junctions among adjacent vessels. A motion-picture film is being prepared which has photographed

through the microscope, frame-by-frame on the film, successive transverse sections of the tree stem at approximately 25-micron intervals, sliced with a microtome knife, much as a butcher slices a long tube of bologna. Each successive section is aligned exactly with that of the previous section, with the effect when the film is projected that the view is literally moving longitudinally through the vascular tissue of the tree. Thus, all the anatomical data of the stem are stored on film and can be retrieved and analyzed three-dimensionally by appropriate slow-motion projection onto a screen. Early results show that in oak trees there are numerous junctions among adjacent vessels as their course is traced from the leaves downward through twigs and branches, with their cross-sectional sizes becoming larger below successive junctions. (Figure 8).

University of
ALASKA 0500

The effect of cold temperature and frozen soil on the water relations of conifers: black, white, and Sitka spruce, and lodgepole pine.

Paul E. Heilman

This project terminated during the year with no report to follow up on last year's statement on soil temperature and moisture relations of white spruce growth.

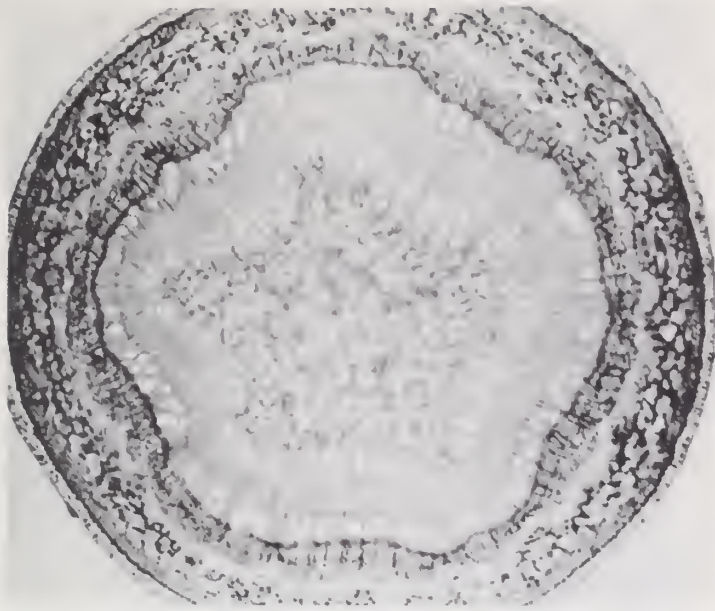


Figure 8. Cross-sections of water-conducting woody tissue of a 70-foot, 40-year-old red oak tree.

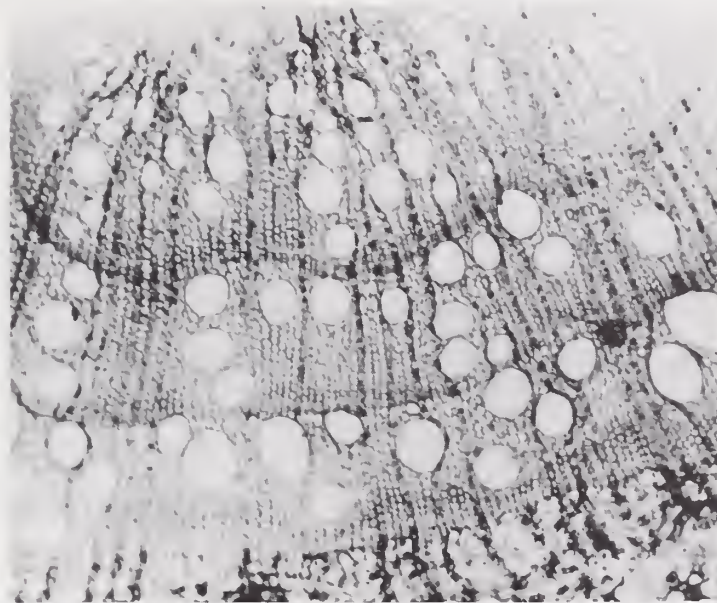
A. Young twig at top

B. Large branch at mid-height

C. Main stem at base

These are intervals in the micro-phototracing of longitudinal connections among the water-conducting vessels.

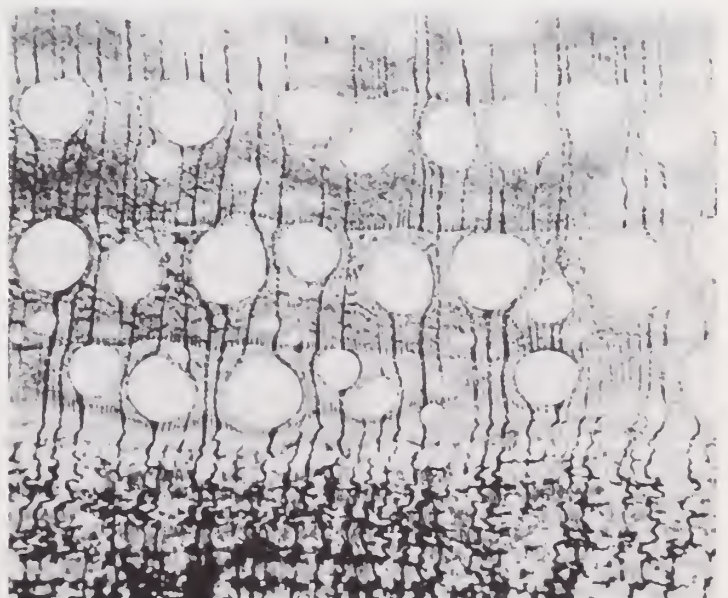
B



The vessels wind their course down the tree from petiole of transpiring leaf to absorbing root.

Note the change from twig's diffuse porous pattern with small vessels to main stem's distinct ring porous pattern with large vessels. University of Michigan 12.

C



OTHER PROJECTS

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- University of FLORIDA 1210. *Nitrogen nutrition and flowering of slash pines.* R. G. Stanley, W. H. Smith.
- University of ILLINOIS 360. *The effects of soil moisture stress on growth and wood characteristics of loblolly pine.* A. R. Gilmore.
- IOWA State University 1582. *Photosynthesis, respiration and growth of seedlings of two Iowa-grown forest tree species in relation to genetic and environmental factors.* Gordon E. Gatherum.
- University of MAINE 5006. *Nutrient content and weight of all components of complete trees as affected by species, age, site and stand density.* Harold E. Young.
- University of MARYLAND L-100. *Vegetative propagation of pine by needle fascicles.* R. L. Baker, I. C. Haut.
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- MISSISSIPPI State University 1122. *Growth and development of the shoot system in conifers of multinodal growth habit.* William W. Elam.
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- NEW YORK - State College of Forestry at Syracuse University A. *Tree growth studies. 1. The influence of vertical growth on the distribution and anatomical characteristics of radial growth in the stem of red pine trees.* Herbert B. Tepper, Hugh E. Wilcox, F. A. Valentine.
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- OHIO State University 5. *Physiology of juvenile growth of trees.* A. R. Vogt.
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- OREGON State University 794. *Transpiration of Douglas-fir seedlings.* William K. Ferrell.
- SOUTH CAROLINA - Clemson University 708. *Moisture stresses in pines.* William H. Davis McGregor.
- SOUTH CAROLINA - Clemson University 853. *Control of gas exchange in pine needles.* R. M. Allen.
- TEXAS A&M University 1649. *Field investigation of water stress and growth in loblolly pine.* D. M. Moehring.
- University of VERMONT 12. *Role of cell transitions in the physiology of some northern hardwoods.* F. M. Laing, J. W. Marvin.

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ECOLOGY

University of
CALIFORNIA 2179

An assessment of the ecological potential of coast redwood.
Edward C. Stone

This research developed around the concept that assessment of the ecological potential of coast redwood will follow naturally the characterization of physiological response of redwood and associated species to environmental gradients that prevail throughout the

geographic area in which redwood occurs. During the past year we focused attention on the physiological potential of redwood and Douglas-fir relative to excess soil moisture--a condition of the alluvial flats on which redwood achieves maximum development.

Mortality of redwood and Douglas-fir differs through their ability to endure prolonged flooding. After flooding for 30 days, redwood seedlings appeared unaffected except for slight foliage discoloration (Figure 9); during similar treatment, 75 percent of Douglas-fir

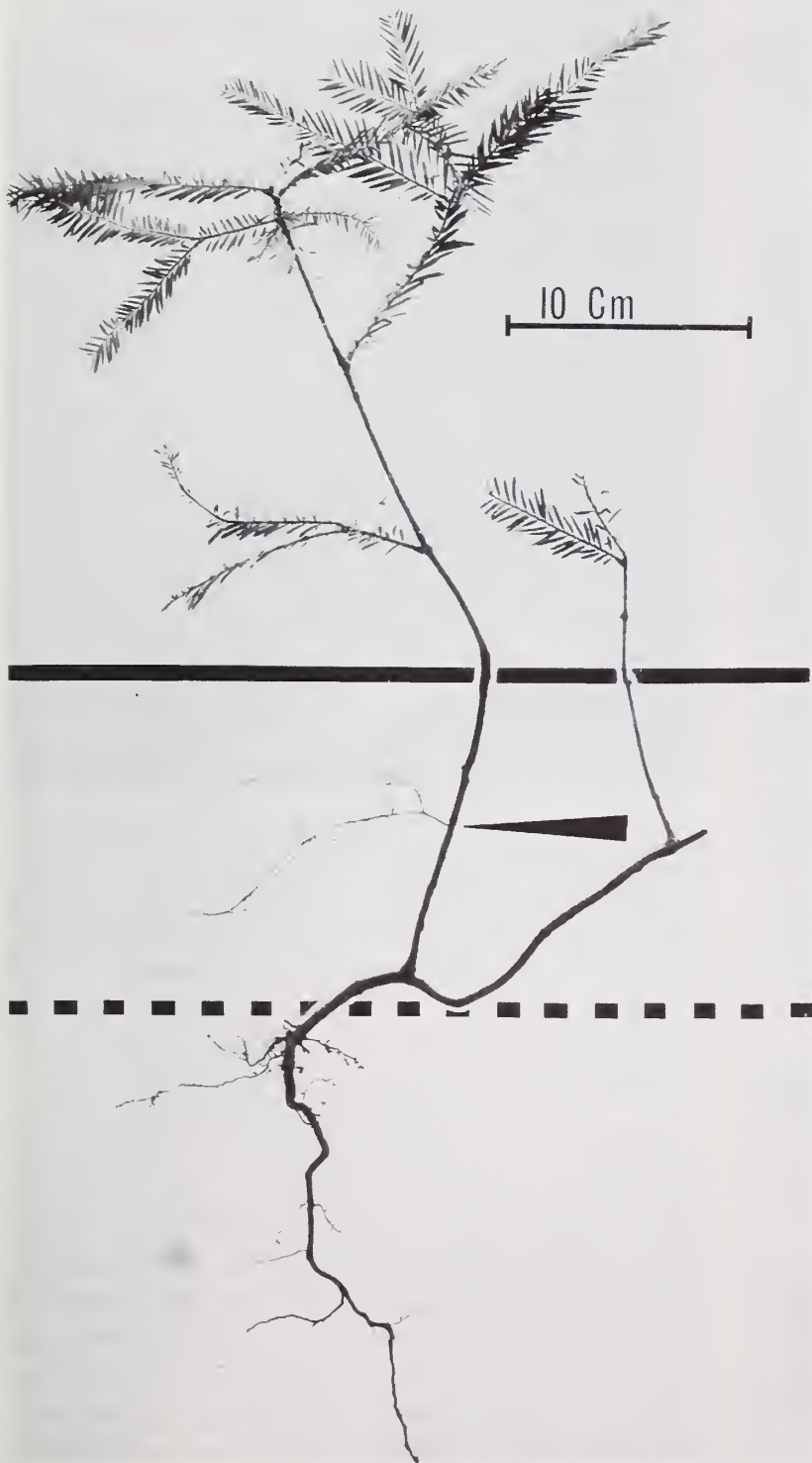


Figure 9. Redwood vitality and adaptability is evidenced in this 12-year-old suppressed seedling that had been virtually buried by silt of the 1964 flood. Surviving to strike a new root system (*opposite the arrow*) the seedling has regained height that scales over 8 inches above the current ground surface (*solid line*). This defines the silt depth as over 5 inches above the 1963 level (*dotted line*). University of California 2179.

seedlings died. Flooding also affected the relative ability of these two species to synthesize and utilize carbohydrates. Apparent photosynthesis dropped off more rapidly in Douglas-fir than in redwood; whereas the reverse was true for respiration. During the first 48 hours following flooding, apparent photosynthesis was reduced by 10 percent in redwood and by 35 percent in Douglas-fir. During the next two weeks, photosynthesis decreased further by 15 percent and 40 percent, respectively. In contrast, during the first 48 hours following flooding, respiration in redwood sharply dropped 20 percent, then remained constant for the next two weeks; while in Douglas-fir it declined 10 percent after two weeks. The net result was that the food reserves in Douglas-fir were quickly exhausted with a large loss in dry weight within less than a week, while in redwood the loss in dry weight was negligible even after 30 days. Flooding affected transpiration little in redwood but caused sharp reduction in Douglas-fir. This either limited Douglas-fir seedlings' uptake of water through roots or loss through their needles. Lacking initial increase in the internal moisture stress, it appears that decrease in transpiration resulted from abnormal behavior of the stomata following flooding.

These results indicate that the physiological ability of the two renowned conifers, redwood and Douglas-fir, to withstand flooding, explains in part their different distribution on alluvial flats and adjacent slopes.

COLORADO
State University 315

Ponderosa pine-bitterbrush. Harold W. Steinhoff
George M. Van Dyne

Plant coactions are one plant's influence upon another. In the ponderosa pine forests of northern Colorado, coactions presumably occur among the three major components: ponderosa pine, bitterbrush, and herbaceous vegetation. This study aims to identify important coactions by their effects upon the shrub component, bitterbrush.

Field work began in the summer of 1967 with analysis of bitterbrush age structure in a dense pine stand that revealed a mean age of 35.7 years. Analysis of 100 bitterbrush plants showed that only plants older than 30 years had accumulated a significant amount of dead material. It is not known if this will be evident for bitterbrush stands in varied degrees of densities of pine or herbaceous cover. Ecologists have speculated on reasons for dead portions of bitterbrush plants--especially the increase in occurrence since 1964.

Following last winter's extensive review and compilation of literature for early forthcoming release, this winter's effort will concentrate on data analysis and thesis writing.

Purdue University
INDIANA 1477

Techniques for forest ecosystem evaluation.

Clair Merritt

Studies in the classification of forests by ordination have shown that an index of uniformity among various locations within forest communities can be derived. The index arises from manipulation of input data in a computer program that accepts field data, computes several parameters, and plots the results in 3-dimensional form. This finding is significant for at least two reasons. One, a method is presented for objectively classifying forests and subdividing them into areas having similar ecological characteristics. Secondly, such classification provides the forester with a better base for prescribing silvicultural treatments on different areas of forest land. He will be better able to predict the results of a given set of treatments in the variety of situations he faces.

Development of the technique of ordination allows the forest ecologist to examine and compare forest communities on a quantitative basis. Communities are all subjected to limitations of their local system--limits of climate, soil, animals and even the vegetation itself. To study several of these major factors simultaneously would be a monumental task. So the trees themselves are used as

the basic measure, that is, measurable representatives of the complex, integrated physical and biological system. Attributes of tree communities, such as number of individuals, their size, and different kinds, are recorded and assumed to epitomize the system. The systems analysis technique of ordination is then used to reveal the interrelationships among these communities by arranging them in a pattern, or ordering them spatially into a three-dimensional constellation. Once their relative positions in this constellation are established, the sound basis provided permits more intensive investigation of influencing system limits.

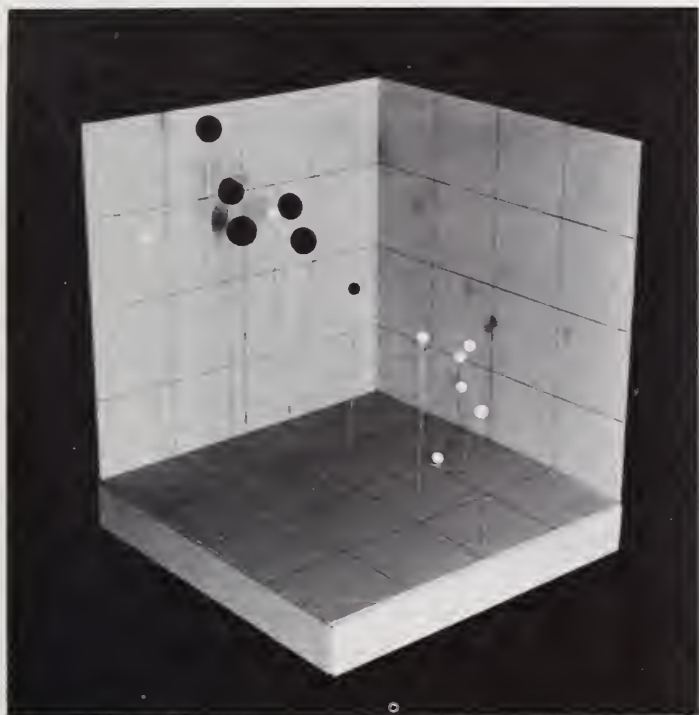


Figure 10. The three-dimensional plotting of attributes of maple stands gives distinctive constellations of the black spheres that represent blighted stands, and the smaller white beads for stands not blighted, Purdue University 1477.

OTHER PROJECTS

University of ALASKA *Forest succession and soil moisture retention on upland sites in the Fairbanks area.*
Bonita J. Neiland.

University of ARIZONA 636. *Nitrogen and carbon balances for forest and range ecosystems in Arizona.*
James O. Klemmedson.

One application of the ordination method helped solve the silvicultural mystery of maple blight, a new and serious problem in the vast hardwoods region of the Lake States. Defying other kinds of analyses, peculiar characteristics of the diseased stands were discovered only after ordination and subsequent study of the three-dimensional constellation. Figure 10 shows this constellation with blighted stands (represented by black circles) forming a discrete group of vegetationally similar communities easily distinguishable from the non-blighted stands (white circles). Statistical treatment of the axes of this constellation provided the key solution of the biological factors making the stands susceptible to this disease.

University of
ALASKA 0540

Forest, bog and intermediate types of the NW Prince William Sound area.
Bonita J. Neiland

This project was terminated during the year with the report that objectives were accomplished. Five permanent transects were established across the transitions between each of four forest bog pairs in an area of subsidence during the 1964 earthquake, and the first year's vegetational data were recorded. Each stand was analyzed for vegetational structure, to determine degrees of similarity with stands in other parts of the Sound; and for soil and peat characteristics, to relate to vegetation of the region. The transects established in the Sound will be rerun in the future to ascertain the effects on these tension areas of changed elevation and, presumably, hydrological features.

Northern ARIZONA University 3. *A study of aeolian and lake deposits to determine past vegetation and climates of the ponderosa pine zone in northern Arizona.*
Dick W. Berry.

CONNECTICUT Agricultural Experiment Station 414. *Multivariate analysis of permanent plot data in hardwood forest.*
David B. Woods.

University of DELAWARE 115. *Wild-land ecology and urban impact.*
Elmer P. Catts.

Southern ILLINOIS University B-4-67. *Dendro-chronological studies in the central Mississippi valley.*
William C. Ashby.

University of MONTANA 1001. *Available soil moisture as a determinant in the distribution and productivity of plants and animals in major forest communities.*
Thomas J. Nimlos.

University of MONTANA 1610. *Photographic interpretation of the forest industry.*
William R. Pierce.

OREGON State University 646. *An ecological framework for forest land management in southwestern Oregon.*
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Michael Newton.

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GENETICS

OREGON

State University 762

Flower induction on juvenile Douglas-fir.

Kim K. Ching, Dennis P. Lavender

Earlier research indicated relationship between flower formation and air temperatures during the key months of January, March, June, and July. This study was designed to test that relationship under controlled environmental conditions. A dependable method of inducing early flowering should reduce the normal interval between germination and flowering, which is approximately 15 years in Douglas fir. This will result in a saving of both time and money in accomplishing the objectives of forest genetics research. A test plantation of 1,584 three-year-old Douglas-fir seedlings was established on a spacing of 42" x 42". The population was divided into 176 plots of nine seedlings each. Three trees of each group were grafted with comparable scion wood taken from mature, fertile trees. The abundance of flowers produced will serve as the measure of effectiveness.

Temperature modifications required are being achieved through the use of portable plastic-covered enclosures equipped with cooling and heating units automatically controlled (Figure 11). Temperatures imposed within the enclosures during January, March, June, and July are monitored by recording devices. The enclosures are removed from the test plantation during the eight months the seedlings are exposed to an uncontrolled environment.

The research design provides for 10 treatments representing different combinations of 4 key months replicated in four series requiring five years for completion. Preliminary results of these treatments will be available in 1968, one year after the first series of treatments has been completed.



Figure 11. Portable plastic covered enclosure equipped with automatic temperature control. *Above:* Exterior view, set down in Douglas-fir plantation. *Below:* Interior, showing test seedlings and monitoring devices. Oregon State University 762.

University of
MICHIGAN 8

Biosystematics of the Betula papyrifera-B. lutea Complex.

Burton V. Barnes

This research dealt with a population of 112 unusual, dark-barked yellow birch, 39 bog birch, and 8 putative natural hybrids in southeastern Michigan. The object was to determine the extent and importance of hybridization and introgression in these birches and elucidate the relationship of the dark-barked birch to yellow birch. Studies of phenology, morphology, cytology, pollen, and seed germination indicated that the 8 intermediate plants were F_1 hybrids between bog

birch and yellow birch. Three additional plants may be backcrosses of the hybrid and one of the parent species.

Bog birch was uniform in morphological characteristics, while yellow birch exhibited a wide range of variation in all characters. This variability may be inherent in the hexaploid species or result from gene flow from bog birch. The dark-barked birch differs somewhat from the classically described yellow birch in the morphology of its pistillate bracts, leaves, and bark. It fits the general description of *Betula alleghaniensis* var. *fallax* (Fassett) Brayshaw. It could be a species distinct from yellow birch, but its general similarity indicates that it is some form of yellow birch. The differences are perhaps the result of genetic isolation from the central yellow birch gene pool, environmental modification, or gene flow from other birch species.

OHIO
State University 2

Seed development in white pine in relation to sterility barriers, inbreeding depression and hybrid vigor.

Howard B. Kriebel

This research shows the possibility of overcoming incompatibility barriers in the soft pines to produce entirely new hybrids. Such hybrids could be valuable if they possessed the combined parent characteristics of high quality of the wood of eastern white pine and the resistance to insects and diseases possessed by certain European and Asiatic species.

Experimental crosses were made between eastern white pine and some other species of soft pines which had never yielded hybrids in numerous attempts by tree breeders. (Figure 12). There was no strong barrier to fertilization after crosses of eastern white

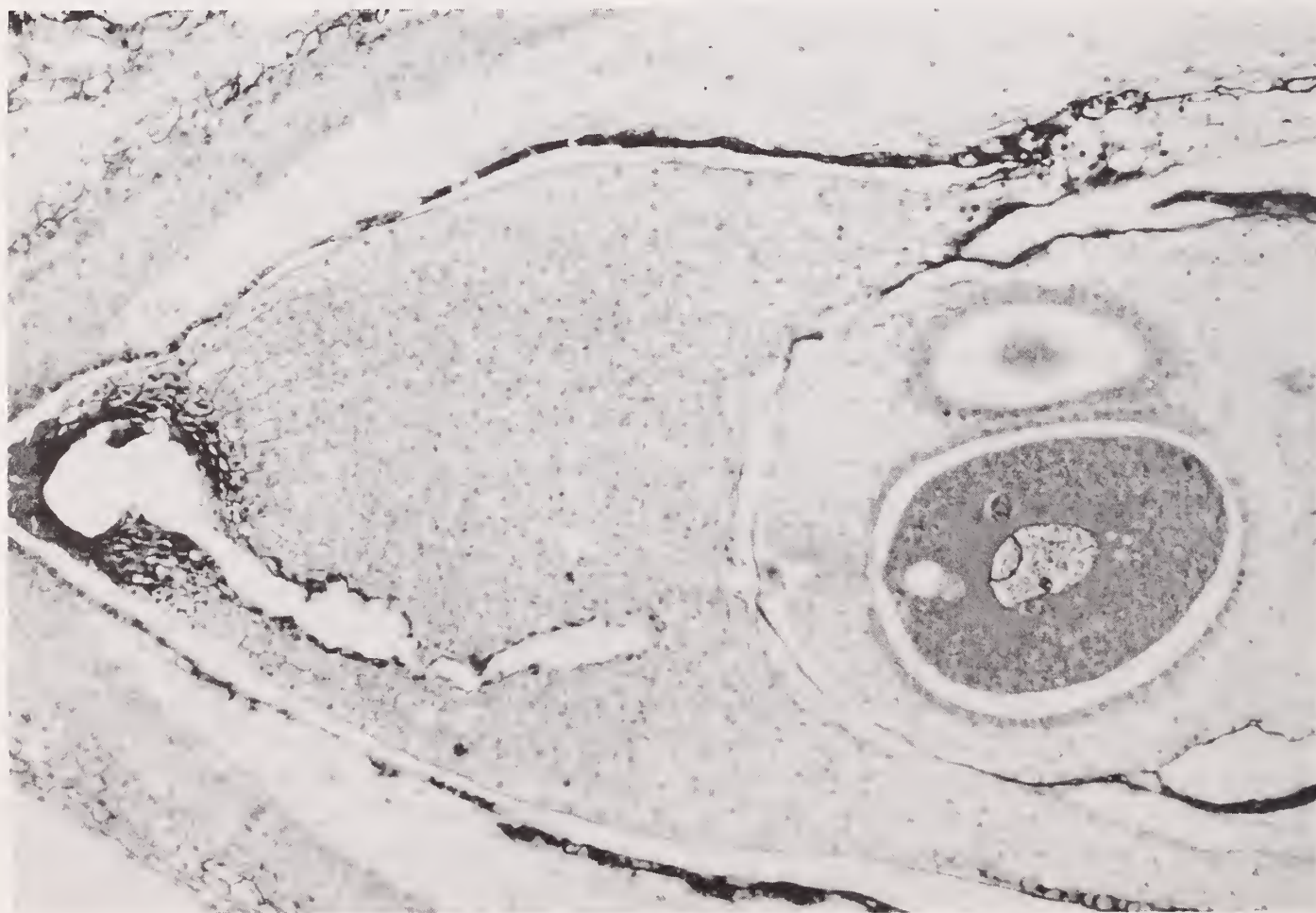


Figure 12. Critical stage in crossing eastern white pine and limber pine to produce a new hybrid soft pine. On right, the large oval is the limber pine egg cell adjoining but still distinct from the smaller light oval of the eastern white pine sperm nucleus with elongated white pollen tube visible in the nucleus. Ohio Agricultural Research and Development Center.

pine and the Swiss stone pine. Some seeds of the cross developed to the point of forming young embryos.

This is first evidence that embryo formation is possible in developing seeds of this species combination. Although breakdown occurred before the embryos matured, the clear evidence that tissue differentiation is possible in this cross opens up the distinct promise of artificially obtaining white pine hybrids previously believed impossible to produce.

University of
WISCONSIN 1262

Cross and self incompatibility in forest tree species.
Donald T. Lester

Artificial crosses were made to determine compatibility in four elm species. Irradiated pollens and pollen mixtures were used in attempts to promote crossing in elm and pine. Crosses using pollen mixes on Austrian and red pine produced about two thousand filled seeds. A probability analysis of seed counts in relation to composition of pollen mixtures indicated that few, if any, hybrids were to be expected. No verified hybrids were noted during the first growing season. Artificial self-pollinations at an early stage of floral receptivity on 35 trees of American elm produced 27 seedling families. Irradiated American elm pollen used alone and in mixture with pollen of slippery or rock elm, resulted in 65 seedlings from five maternal American elms. Seedlings theoretically could be polyhaploids, interspecific hybrids, or selfed progeny. Chromosome counts have ruled out polyhaploidy for most of the plants. Interspecific hybridity remains a possibility for some. Artificial self-pollinations on slippery elm and on Siberian elm produced a few filled seeds which are being stratified in preparation for germination tests. Siberian elm x slippery elm and the reciprocal cross produced many filled seeds whereas Siberian x rock elm produced no filled seeds.

NORTH CAROLINA
State University 4001

Natural variation, introgression, and taxonomic relationships among members of the slash pine complex.
Leroy C. Saylor

This project was terminated during the year with a full report of objectives accomplished. Statistical analyses of natural populations provided information of value to taxonomists and tree breeders. For *Pinus caribaea*, significant variation exists between groups of islands. The magnitude of variation present in such characters as growth and wood properties indicates this pine has great potential for use in tropical and subtropical countries.

The information obtained on wood properties is of particular value to pulp and paper manufacturers. Results indicate that wood from the Caicos Islands is lighter than that of the Bahamas Islands; significant differences also occur among the Bahamas Islands. *Pinus caribaea* from the islands has wood of higher density than the slash pine (*P. elliotii*) of Florida. For fiber length, material from the Caicos Islands is shorter than that of the Bahamas Islands but is about equal to that of the Florida slash.

The very large tree-to-tree component of variation in Bahamian pine suggests mass selection may be a very effective breeding method. Breeding by intervarietal and interspecific hybridization would also appear to be promising for the future. Within the species *Pinus caribaea*, varieties *bahamensis* and *caribaea* appear to be more closely related to each other than either is to var. *hondurensis*. Florida slash pine is a much more variable species than *Pinus caribaea*. Variety *bahamensis* is similar in many ways to varieties *densa* and *elliotii* of *Pinus elliotii*. Hybridization studies indicate that var. *bahamensis* is the most cross compatible with var. *elliotii*. Information was obtained to suggest that a Central American hard pine might have been the ancestral form from which forms of both *Pinus caribaea* and *P. elliotii* evolved.

University of
Washington 2

*Leaf and flower development in tomato affected by
the lanceolate gene.* Reinhard F. Stettler

This project was terminated during the year
with a report on accomplishment of objec-
tives. The growth curves of total leaf length
are different for the genotypes studies. The
ultimate differences in leaf shape can be de-
tected when the leaves are 1 - 2 mm long.

OTHER PROJECTS

ALABAMA - Auburn University 903. *Development
of improved forest trees for Alabama.*

James F. Goggans.

COLORADO State University 311. *Forest genetics.*
Gilbert H. Fechner.

University of FLORIDA 1293. *Stock-scion relation-
ships of southern pine.* W. H. Smith.

University of FLORIDA 1320. *Fusiform rust resist-
ance in slash pine.* Ray E. Goddard.

University of FLORIDA 1344. *Improvement of
sand pine for reforestation of the Florida sandhills.*
Ray K. Strickland, Ray E. Goddard.

University of IDAHO 3. *Heritability of important
economic characters and population structure of
ponderosa pine.* Chi Wu Wang.

MICHIGAN Technological University 2. *Genetics of
sugar maple.* Robert L. Sajdak.

MICHIGAN State University 936. *Mineral nutrition
and differential physiological response of trees to
environment, as related to within-species genetic
variation.* Donald P. White.

University of MINNESOTA 19-78. *Hybridization
studies in Populus.* Scott S. Pauley.

University of MISSOURI 534. *The role of moisture
in pine pollination.* R. Brooks Polk.

University of MISSOURI 607. *Genetic investigations
in forestation.* R. Brooks Polk.

University of MONTANA 904. *A study of the
putative hybrid of Larix occidentalis Nutt. and
Larix lyalli Parl.* George M. Blake.

They result from a variety of growth patterns.
Several attributes of lanceolate plants, (de-
viant cotyledons; low number of flowers per
inflorescence, low seed yield) have been
shifted towards "normal" through our back-
cross program. This means that the expres-
sion of the lanceolate gene depends on the
genetic background and that there may be
specific modifier genes involved in this in-
teraction.

NEW YORK - State College of Forestry at Syracuse
University F. *A program of genetic improvement
in hardwood forest trees.* Gerald R. Stairs.

NORTH CAROLINA State University 4015. *Geo-
graphic variability in yellow-poplar.*
Robert C. Kellison.

NORTH CAROLINA State University 4016. *A
study of the relationships among Pinus rigida Mill.,
P. serotina Michx., P. taeda L., and P. echinata
Mill. in areas of sympatry.* Leroy C. Saylor.

OKLAHOMA State University 1241. *Phenotypic
variation in morphological characteristics of Okla-
homa shortleaf pine.* Clayton E. Posey.

OKLAHOMA State University 1304. *Development
of improved forest trees for Oklahoma.*
Clayton E. Posey.

OKLAHOMA State University 1348. *Evaluation of
the growth, yield, and pest resistance of shortleaf x
slash pine hybrids.* Clayton E. Posey.

OKLAHOMA State University 1349. *Cottonwood
improvement.* Clayton E. Posey.

OREGON State University 759. *Inter- and intra-
family variation in Douglas-fir.* H. Irgens-Moller.

OREGON State University 760. *Douglas-fir seed
development.* W. P. Wheeler.

SOUTH CAROLINA - Clemson University 704.
Genetic studies of forest trees. Roland E. Schoenike.

SOUTH CAROLINA - Clemson University 705. *In-
breeding Virginia pine.* Roland E. Schoenike.

SOUTH CAROLINA - Clemson University 717.
Genetic improvement of oaks. Roland E. Schoenike.

WASHINGTON State University 1771. *Genetic and ecological bases for multinodalness in lodgepole pine.* Richard M. Dingle.

University of WASHINGTON 16. *Genetic studies of Pacific Northwest hardwoods.* R. F. Stettler.

University of WEST VIRGINIA 1. *Selection, propagation, and silvicultural regeneration of genotypes of hardwood tree species.*

Franklin Charles Cech.

University of WYOMING 940. *The variations in and ecology of aspen in Wyoming.* Alan A. Beetle.

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Wheeler, W. P.

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Forest Protection

Each of the constituent fields--forest fire, forest pathology, and forest entomology--has a wide scope of research. This ranges from fundamental research where outcome is an open question to oriented research where favorable cost-benefit ratios are pre-requisite. Logically, efficient research in the critical zone examines both plus and minus effects of variables on the outcome--whether to be attained or to be avoided. Thus, research on either the beneficial or the injurious aspects challenges the same skills, capacities, and knowledge of the scientist. Quite naturally, some projects have become identified with subject matter of the outcome; thus, research involving fire effects shows up under soils, ecology, silviculture, recreation, watershed, wildlife and range. The few projects grouped under fire represent a good beginning of research dealing directly with burning in tests or uncontrolled fire.

Forest pathology has a traditionally broad spectrum of research: benign parasitic fungi that develop mycorrhizal roots of pine seedlings; malignant, world-wide, root-rot fungus *Fomes annosus* that persists in the managed coniferous forest; ubiquitous nematodes--animals, too small to see, too many to count--that exact a heavy toll on growth and yield; the needle and broad-leaf foliage disorders involving atmospheric ozone and other environmental pollutants; and finally, wood deterioration, tree blights and diseases incited by fungi and bacteria.

Forest entomology deals with myriad forms of insects, such as, beneficial pollinators of tree flowers, vectors of tree disease, stinging wasps, wood borers, defoliators, and tree killers. Also, included are spiders, mites and microfauna intrinsic to forest soils in ecosystems. The three fields of protection research are anchored in the most fundamental disciplines, and bridge the incredible gap between forest biology and forest management toward utilitarian, operational and economic goals.

FIRE

University of
WASHINGTON 12

Influence of fire on forest soils.

Dale W. Cole

The overall purpose of this investigation is to determine the effects of fire, both controlled burning and wildfire, on the mineral nutrient regime of forest soils. To determine if nutrients are lost from the nutrient cycle following a fire, it is necessary first to examine the variables involved as separate entities and then to examine variables that interrelate out in the field. Three principle variables that govern the physical effect of a fire on a soil are: a) the intensity of the fire, i.e. heat output per unit time; b) the

duration of the fire, and c) the soil moisture content. The first step is to quantify some variable heat source and then to measure its effect on a dry soil (preferably a model soil). The heat source should approximate the heat released by a fire burning in normal forest fuels; and measurements made first with the heat intensity held constant and time as a variable, then conversely with time held constant and heat varied. The foregoing portion of the investigation has been accomplished. Data from two soils, one a sandy soil and the other a model soil constructed of uniform diameter (110 micron) glass beads have been subjected to heat flux measurements as air dry systems. The next step will be to measure the heat flux in soils with varying moisture contents, especially

with moisture approaching permanent wilting point of 15 atmospheres--the normal soil moisture state during fire season.

The measurements to be made at high soil moisture tensions with instruments to make these measurements is severely limited. The best method would be to use the soil moisture psychrometer--a small porous chamber which is placed in the soil. This chamber contains a small thermocouple that is connected through a switching device to both a known current source and to a non-voltmeter. To make a measurement, the thermocouple is first cooled by passing a current through it that causes moisture to collect; then, the thermocouple output is measured. The thermocouple is then heated by reversing the current and the output is again measured--the difference in emf's may be correlated with soil moisture tension.

University of
MONTANA 302

Use and effects of prescribed burning after timber harvesting in the northern Rocky Mountains.

Robert W. Steele

To date, research has concentrated on effects of clear-cutting and burning on regeneration and browse production; also on use by domestic livestock and wildlife. In the use and effects of prescribed burning within areas of standing timber for thinning and cleaning, 18 sample burns have been conducted in young ponderosa pine at three levels of fire weather severity. These sample burns have indicated the feasibility of change of fire intensity through manipulation of the fire front. The release of selected crop due to the

thinning is now being followed by periodic measurement of trees that survived the thinning fire.

COLORADO

State University 316

Effects of forest fire.

W. David Striffler, Edwin W. Mogren

In August 1966, a severe fire killed all the vegetation and destroyed all the surface organic material on 600 acres of lodgepole pine and spruce fir forest near Comanche Reservoir. During the summer of 1967, studies were made on the rate of erosion in the burned area and the effect of the fire on the hydrologic characteristics of the forest floor. (Figure 13)

Observations from 20 erosion plots within the burn indicate that during the summer of 1967 erosion was not a serious problem. This is attributed to the rocky character of the soil surface, and the lack of severe storm activity over the burn. However, studies using techniques of soil particles tagged by both dyes and isotopes show that erosion is occurring on the denuded slopes; that rain-drop splash on the bare soil surface is the primary motivating force; and that soil particle movement is largely confined to micro channel systems downslope from the plots. Most entrained soil particles were subsequently redeposited in depressions or behind barriers at down-slope points. Series of 50 samplings were established both for soil analysis and ecological observation on fire effects.



Figure 13. Effects of intense fire on lodgepole pine forest. *Above:* Complete kill of all trees. *Below:* All litter consumed. Colorado State University 316.

OTHER PROJECTS

University of CALIFORNIA 2351. *Relation of composition and distribution of vegetation to fuels on wildlands.*
Arnold M. Schultz.

LOUISIANA Polytechnic Institute 2. *Effects of annual burning on site quality of longleaf pine.*
Edward R. Andrulot.

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Steele, R. W. and W. R. Pierce.
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PATHOLOGY

Auburn University

ALABAMA 907

Biology of fungal pathogens associated with littleleaf and seedling diseases of southern pines.

Walter D. Kelley

Studies are active on the effects of individual soil organisms on sporangial production of *Phytophthora cinnamoni*. Soil organisms isolated from sporangial-inducing soil leachates are currently being tested individually for their ability to induce *Phytophthora* to form sporangia. Organisms will be identified and maintained in culture for further studied to isolate the sporangial-inducing substances.

A field study on the control of foliar diseases on Arizona cypress seedlings in nursery beds is still in progress. Several fungicides and application rates are being tested on a two-week spray program; the fungicides are Duter W-50, Cyprex, Manzate, and TC-90. On the basis of monthly samples through October, Cyprex at the rate of 2 pounds per 100 gallons of water provides the best protection from foliar pathogens.

PENNSYLVANIA

State University 1488

An annual canker of maple.

W. W. Ward, F. A. Wood

Germination of spores of the fungus *Fusarium solani* was stimulated by water extracts of the inner bark, the cambium, and the outer wood layers from sugar maple in comparison to germination in water alone. The extracts from inner bark tissue provided the greatest stimulus of the four treatments. Spore germination was significantly greater in extracts collected in October than in those collected in April. The several species of fungi, *Fusarium solani*, *F. roseum*, *F. rigidisculum* were isolated from the bark of healthy trees, and from the soil of stands containing healthy and diseased trees. Inoculations with isolates of all these species resulted in cankers indicating that *Fusariums* other than *F. solani* may be involved in this disease.



Figure 14. Sapling sugar maples subjected to below-freezing temperatures by a refrigeration technique using carbon dioxide. Thermocouples are used to monitor temperature changes at the bark surface and at the cambium. Pennsylvania State University 1488.

A comparison of twenty-five pairs of healthy and diseased sugar maples showed that the diseased trees had significantly thinner bark than the healthy trees. Artificial freezing experiments in April and October, utilizing a carbon dioxide refrigerating system (Figure 14), were conducted to test the hypothesis that sudden changes in temperature may cause minute breaks in bark of thin-barked trees and thus provide avenues for infection by *Fusarium* species.

Correlations between standard weather station data and microclimatic data collected in stands of high canker incidence may provide further information on the relative susceptibility of stands to maple canker disease.

University of

MASSACHUSETTS 7

Lophodermium needle cast disease and ozone damage of white pines.

Walter M. Banfield

Three-year-old seedlings of eastern white pine were selected from the nursery on the basis of the profuse spotting of their needles and chlorosis of the foliage. When these

seedlings were potted and grown in a greenhouse into which air was admitted only through cotton and charcoal filters, they produced vigorous new foliage that remained flawlessly healthy.

Groups of these healthy but susceptible pine seedlings were exposed to ozone at different times from June to September. Only continuous exposure to ozone concentration exceeding 18 pphm for periods of more than 3 days induced profuse spotting and blight. These symptoms were present at the close of the fumigation period. They did not intensify with time after transfer to the double filtered greenhouse.

When groups of these pine seedlings were exposed to outside air for a week or more at different times between July and October and then returned to the filtered greenhouse, they developed profuse spotting. In several trials some or all of the susceptible trees exposed for 3 to 10 days to *Lophodermium pinastri* in a closed mist chamber developed profuse spotting.

The needle spot symptoms induced on some of the ozone-exposed trees were indistinguishable from those induced by exposure to *Lophodermium*. However, the spot symptoms that followed exposure to *Lophodermium* did not become visible until several weeks after they had been returned to the filtered greenhouse.

University of
WISCONSIN 1264

Oak wilt: its development, spread and control.

James E. Kuntz

Disease control: More effective measures were sought to control the oak wilt disease in both woodland and residential areas. Different soil fumigants including Vapam, Vorlex, Mylone, and methyl bromide, used to chemically "sever" grafted roots, prevented further tree-to-tree spread (Figure 15). Fumigants were evaluated at different dosages and injection depths, on different dates, and in different soils. Effective chemicals and treatments have been defined and



Figure 15. The control of tree-to-tree spread of oak wilt by soil fumigation with "Vapam". The disease progressed from right to left up to barrier marked by position of pickup truck. University of Wisconsin 1264.

are now being used commercially, not only for control of oak wilt, but also the Dutch elm disease. Fumigation action on treated roots will be clarified by histological studies. Silvicides, including cacodylic acid, disodium methylarsenate, and other chemicals less toxic than sodium arsenite, killed treated trees and prevented spread of the fungus from infected-treated trees.

Possibly chemotherapy of the oak wilt disease has tested various fungicides including DuPont 1991, antibiotics such as cycloheximide, phytoactin, and aurofungin and, more recently, growth regulators such as Tritac, TCPA, kinetin, and cytokinin. Tests since 1964 have shown that best treatments either have delayed symptom development or protected inoculated trees. Presently, the basis for such protection is sought.

Nutritional studies have shown greatest disease incidence and symptom development in trees suffering from nutritional deficiencies

or excesses. Sap from resistant and susceptible oaks is being analyzed for different amino acids and sugars.

Current histological studies, using special light and electron microscopes, already have clarified the time, place and manner by which water-conducting vessels are plugged in different oak species, "trapping" of the fungus by such physical barriers, restriction of fungus penetration by host metabolites, and growth effects. The oak wilt fungus not only penetrates cells, but also degrades cell wall components. Wilt and resistance mechanisms are sought. Antagonism in preliminary studies indicates that the oak wilt fungus did not incite foliage wilt when certain other vascular wilt organisms had been introduced previously into the inoculated trees.

Results of current oak wilt studies provide effective and practical control measures for vascular wilt diseases of both forest and shade trees. These studies also have clarified wilt mechanisms and bases of host resistance.

University of
WISCONSIN 1434

Etiology, epidemiology, and control of forest plantation root diseases. **Robert F. Patton**

The root rot fungus, *Polyporus tomentosus*, has been found in Wisconsin attacking red and jack pine and white spruce. The exact site of infection, however, has not yet been determined. The spread of the fungus infection centers, such as the individual infected-root systems in pine plantations and the "pockets" of infection as seen in the infected spruce stand, is being studied to determine the rate of movement in roots and the mode of spread. Root systems in a number of spruce infection centers were exposed by washing with both high and low pressure streams of water. Infection occurred on scattered individual roots rather than in the entire mass of roots within the "pocket". A number of points were observed where spread occurred by root-to-root surface contact (Figure 16); grafting of roots was not observed and was not necessary



Figure 16. This tree in a white spruce plantation was dead and all of its roots invaded by *Polyporus tomentosus*. The root running from left to right and across the top of a diseased root from the tree, was healthy on both sides of the crossing but was invaded by the fungus at this and one other contact point. University of Wisconsin 1434.

for spread of the fungus from an infected to a healthy root.

Margins of infection in a plantation, previously defined by distribution of fruiting bodies in the fall, must now be considered as extending much farther out from the infection center than originally thought. This is because of the likelihood of trees outside the original margins being infected by root contact with inside-infected trees. The rate of movement and consequent damage to root systems is not known precisely; however, observations in these washed-out root systems indicate that the fungus moves relatively slowly--especially as compared with the more dangerous *Fomes annosus*, which to date has not been found in Wisconsin.

Sporulation of the fungus in the field is related to temperature and moisture conditions. Spores have been released at temperatures as low as 4°C; at temperatures of 36°C and above, the fungus is inactive. A high sporophore moisture content, which is governed by the environmental conditions, also favors abundant sporulation.

Conditions which influence basidiospore germination are being studied to help determine the role of basidiospores in the initiation

of new infection centers. Cold-water extracts of bark of both pines and white spruce contain a heat-stable substance which markedly stimulated growth of the fungus in culture as well as increased the percentage of spore germination.

University of
MINNESOTA 22-18

Dwarf mistletoe.

D. W. French

In previously reported work it was shown that clear-cutting to control dwarf mistletoe did not eradicate the parasite, and 4 years later the number of infected trees averaged 15.6 per acre. Next, fire was used as a means of eradication and on rod-square plots sprayed with oil and then burned, every spruce tree on every plot was killed. If this can be accomplished on larger plots, the disease can be controlled because the parasite can not survive once the host is killed, and long-ranged dissemination occurs infrequently. This year, 23 infection centers were located, marked, characterized and mapped for a series of oil and burn experiments. A single tenth-acre plot was burned on May 17 with moderate fire danger conditions. Lateral fire spread was incomplete, indicating that major burning tests planned for the spring of 1968 must be made when the relative humidity is lower.

The distribution of dwarf mistletoe in Minnesota has been determined for three hosts--black spruce, white spruce and eastern larch. Pollination, fertilization, maturation of fruit, and seed dispersal of eastern dwarf mistletoe is in general agreement with that published for western species except that the eastern species completes the entire process in one season, while western

species require two seasons. Seeds of this eastern species are forcibly expelled to a distance of 7.2 feet (maximum 17 feet). At 12 feet above ground they can be shot 11.7 feet (maximum 23 feet). The seed germinated from May through July, and the radicle penetrated the spruce host immediately. By September 30, penetration of host was accomplished and thus new infection established. Only 25 percent of the seeds germinated. The remainder of the seeds were either non-viable or had been parasitized by a fungus, which could serve as a biological control. On birds that were trapped, no seeds were found, although it is assumed that birds are the major means of establishing new infection centers. Four year-old trees of all three conifers have been inoculated with seeds to follow the host reaction to the parasite.

OKLAHOMA

State University 1238

Effect of site quality and mycorrhizae on establishment and development of shortleaf pine.

Theodore H. Silker,
Lester Reed, John Thomas.

The project was terminated with a report: Three annual greenhouse tests and supplementary field studies suggested mycorrhizae incidence in soils relates to soil profile nature and frequency of certain native hardwood plant associations. Physiological development (both top and root) of shortleaf pine grown on the three soils was proportionate to mycorrhizae incidence. Mycorrhizae frequency appears sufficient under certain native plant groups west of the commercial pine-hardwood boundary to provide adequate inoculation of direct-seeded pine.

University of CALIFORNIA 2348. *Microbiology and pathology of wetwood in California firs.*

W. W. Wilcox.

University of CALIFORNIA 2383. *Studies on the epidemiology and control of Fomes annosus root rot.*
Fields W. Cobb.

OTHER PROJECTS

University of ARIZONA 621. *The biology and control of fungi pathogenic to forest vegetation.*

Wilhelm Gearhard Solheim.

University of ARKANSAS 663. *Organelles of fungi causing forest-tree diseases.*
C. L. Wilson.

- University of HAWAII 715. *The ecology of Phytophthora cinnamomi* Rands in forest soils.
E. E. Trujillo.
- University of IDAHO 11. *Ecology as a means of cull estimation in western redcedar.* A. D. Partridge.
- LOUISIANA Polytechnic Institute 5. *The morphology and cytology of the pine-oak gall rusts in the South and the relationships with their coniferous and angiospermous hosts.* F. F. Jewell.
- University of MARYLAND J-101. *Forest tree seedlings and soil fungi relationships.* W. L. Klarman.
- University of MASSACHUSETTS 1. *Etiology of maple tree decline in Massachusetts.*
Donald L. Mader, George N. Agrios,
Walter M. Banfield, William B. Becker,
Francis W. Holmes, Richard A. Rohde.
- University of MASSACHUSETTS 6. *Viruses and virus diseases of forest hardwoods.*
George N. Agrios.
- University of MICHIGAN 11. *Relationships of small mammals and birds to eastern gall rust on jack pine in northern Michigan.* George S. Hunt.
- University of MINNESOTA 22-17. *Ecology of wood decay.* D. W. French.
- University of MISSOURI 540. *Fomes annosus root and butt-rot of Pinus echinata in Missouri.*
Theodore W. Bretz, deceased.
- NEW YORK - Cornell University 901. *Effects of ectotrophic mycorrhizae on tree growth.*
Earl L. Stone.
- NORTH CAROLINA State University 4012. *Ecology of forest tree diseases.*
David W. French, Ellis B. Cowling.
- OREGON State University 819. *Phytophthora root rot.* Lewis F. Roth.
- PENNSYLVANIA State University 1702. *Epidemiology of forest tree diseases.* F. A. Wood.
- University of PUERTO RICO 1. *Diseases of forest trees.* J. H. Lopez-Rosa.
- University of TENNESSEE 7. *Blight resistance in American chestnut.* Eyvind Thor.
- TEXAS A&M University 1526. *Etiology and control of live oak decline.* Robert S. Halliwell.
- University of WASHINGTON 8. *Biological potential of Fomes annosus (Fr.) Karst. under intensive stand management condition in Northwest forests.* Charles Driver.
- WASHINGTON State University 1770. *Development and pathogenicity of Hypoxylon fuscum in northwest species of alder.* Jack David Rogers.
- University of WYOMING 928. *Diseases of aspen in Wyoming.* E. A. Andrews.

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ENTOMOLOGY

University of
ARKANSAS 611

The control of pine sawflies in Arkansas with special reference to the use of biological control agents.

Lloyd O. Warren, J. P. Fulton

Screening and field tests conducted in 1964 and 1965 with candidate pesticides resulted in the replacement of DDT, a long-lived environmental contaminant, with Diazinon as a chemical control treatment for epidemic infestations of the pine sawfly, *Neodiprion taedae linearis*. Diazinon is competitive in cost with DDT and poses much less hazard to the environment. Other candidate materials tested were also very effective in controlling this pine sawfly at low dosages, but have not yet been registered for use on forest lands.

Investigations on biotic control agents in 1966-1967 emphasized the biology of a hymenopterous parasite of the cocoon stage of the sawfly. This is one of the most common parasites associated with the pine sawfly in Arkansas; it was easily reared under laboratory conditions through four generations. The life cycle is short, averaging 16 days at 25.5°C; evidence indicates this parasite is multivoltine and has more than one host species.

This primary parasite (in a taxonomic group being revised) is subjected to hyperparasitism by an unknown dipteroid. The larva of the hyperparasite attaches itself to the cuticle of the sawfly larva. It remains attached into the cocoon stage of the sawfly, which apparently suffers no ill effects from its presence even though up to 25 were observed on a single sawfly larva. When the primary parasite larva begins to develop on the sawfly prepupa, it is attacked and killed by the hyperparasite. Studies on the effect of the photoperiod showed that at day lengths of less than 12 hours, continuous rearing of this sawfly was possible. While adults have been obtained under artificial conditions, eggs from these adults did not hatch. Further investigations are needed to clarify the problem of continuous rearing of this sawfly for experimental use.

University of
IDAHO 5

Effects of methyl demeton on Douglas-fir and its cone and seed insects and rodent indicator species.

John A. Schenk

The introduction of systemic insecticide into the trunks of Douglas-fir by means of "Manuget Tree Injector Units" was proved feasible. Injections of 24 grams of oxydemetonmethyl per tree (2 gms per diameter inch) significantly reduced insect-caused seed losses in open-growing, pole-sized trees in 1964. A highly significant increase in mortality of the cone moth, *Barbara colfaxiana*, and a substantial reduction in galled seeds also was obtained in the treated cones. In 1965, the applications at half the above note influenced mortality in only two collections.

Oxydemetonmethyl did not produce discernible symptoms in treated Douglas-fir and did not affect germinative capacity, nor, seedling growth or development. Test colonies of white mice and deer mice fed treated cones showed no difference in behavior, fertility, and survival of young from those colonies fed untreated material.

The results of this study show the feasibility and effectiveness of "selective treatment" by use of trunk-injected systemics. If only genetically superior, cone-bearing trees in a cone production areas, seed orchard, or forest stand were treated, the impact of the cone and seed insects could be utilized to establish a more productive stand by destroying seed, hence reproduction, from inferior trees. This practice would be less costly than broadcast application and less disrupting to the faunal ecology. Returns from marketable material and increased yield might further justify the practice if it were done in conjunction with commercial thinnings or sanitation cuts.

KANSAS

State University 671

Forest tree entomology.

Paul L. Roth

Eastern redcedar was observed to be the preferred and most seriously injured host of the tortricid moth, *Choristoneura houstonana*--although other junipers are attacked. Eggs

were laid singly, or in pairs from early July to mid-August. Eggs were found in greater numbers on foliage in the upper and south-facing parts of the host tree; egg hatch occurred in about 10 days. This species averaged 9 instars based on head capsule width, rearing of larvae under laboratory control, and count of crochets on the prolegs. The larva, on hatching, quickly mines the host foliage very near the egg and continues to feed in passing through instars 1 to 3. Upon reaching third instar, the larva constructs a hibernaculum within the mine, moults to the 4th instar and goes into diapause. On infested trees grown in greenhouse chambers at varied exposure of 8 to 24 hours of continuous light, *C. houstonana* larvae exposed to less than 14 hours of light, entered diapause; however, those exposed to more than 14 hours of light continued to feed, passed through all larval instars, pupated, and emerged as adults at about 90 days in early November. In April, the 4th instar larvae emerge from the hibernaculum and mine, move a short distance, web a number of shoots together and feed on the foliage within the web to cause great injury to redcedar. Pupation takes place in the web--lasting 10 days in June-July. Adult moths emerge during the day, but activity begins after darkness. Mating occurred within 24 hours, starting at dusk, continued through the night, and terminated about 3 a.m. About 110 eggs were produced by each mated female.

Six spider and one Hemiptera species were observed to prey on *Choristoneura houstonana* larvae and adults; one dipterous and five hymenopterous parasites on larvae and pupae were reared from field collected infested foliage.

University of
MAINE 5001

Susceptibility of various forest stand types to pine leaf aphid damage.

John B. Dimond

An outbreak of the pine leaf aphid commenced in Maine about 1953, reached a peak in 1961, and has since declined. It was noted that the insect became very abundant in some

portions of the state while remaining rare in others. Moreover, within the areas of high aphid populations, some stands of white pine sustained heavy damage while others did not. A study commenced in 1964 to explain these differences in susceptibility and vulnerability to pine leaf aphid attack (Figure 17). It was hoped that such explanations might suggest means of reducing the vulnerability of stands through prescribed cutting or other management practices.

It can now be reported that the pine leaf aphid outbreak was restricted to forests occurring on certain soil types in Maine. These soils are alluvial sands and gravels produced by glacial outwash or stream activity. It is only on such soils that one finds extensive forests with large components of both white pine and red spruce. The aphid requires both of these host tree species in order to complete its life cycle; however, damage occurs only to the pine. The appropriate soils, and the susceptible forests are located in southeastern and west-central Maine. Farther north, the soils are heavier loams, the spruce is abundant but, pine dwindles in numbers to the point that the forests cannot support large aphid populations. Sandy soils predominate in southwestern Maine and white pine is abundant. The climate is so warm and dry, however, that red spruce is uncommon, and again the aphid is rare. In general, susceptible forests contained at least 20 to 35 percent of both white pine and red spruce. Where either one or both of the host trees was substantially less common, the aphid was not abundant.

It was possible to bring out a relation between increasing quantities of spruce in a stand and increased damage to the pine present. While the mathematical relationship is not precise, it provides general guidelines for predicting from a knowledge of the quantities of spruce and pine in a stand, the amount of pine damage that might be expected in subsequent aphid outbreaks. One can also predict how much reduction is required in the spruce component of the stand to reduce pine damage to tolerable levels. Additional information was obtained in the



Figure 17. Aspects of pine leaf aphid injury in the recent outbreak in Maine. *Left:* Contrasting pine crowns: The defoliated tree is an eastern white pine with severe foliage loss caused by repeated attack by the pine leaf aphid. The adjacent normal crown is red pine—a species not attacked by this aphid. *Right:* Cone-like galls on red spruce caused by infestation of the pine leaf aphid. From these galls, winged aphids emerge to fly to eastern white pines. University of Maine 5001.

study on how vulnerability of pine is influenced by size of trees, density of stands, etc.; however, none of these factors is as important in determining amount of damage as the relative quantities present of the aphid host plants, pine and spruce.

MICHIGAN

State University 942

Investigations on autostability of the arthropod component in single species conifer ecosystems.

J. W. Butcher

This is a long-term study in depth of the indigenous fauna in plantation conifer ecosystems. It aims to establish a basis for studying the relationships of parasitic and predatory arthropods to tree feeding forms, once the fauna are catalogued. Limited funding modified this study to emphasis on census of ground-inhabiting, as well as winged forms in planted Scotch pine, and planted and natural jack pine. Some 64 species of spring-tails, ground beetles, and spiders were identified and abundance related to soil type, herbaceous vegetation, and chlorinated hydrocarbon residues in the soil.

Injury by pine root collar weevil is the subject of a cooperative study. A censusing device is used to determine weevil abundance (Figure 18). Data on mineral content, mois-



Figure 18. Inexpensive insect trap collects weevils that are diverted by screen into jar with tanglefoot. Weevil abundance is correlated with site characteristics. Michigan State University 942.

ture holding capacity, texture of the soil and foliar analyses are being computerized to test whether weevil injury is site related. A study of the relationship of jack pine shows that insects are the major factor in growth, survival, and distribution of *Melampyrum*.

For the first time, malaise traps have been used in quantitative studies of arthropods in

cyclodiene treated woodlots to evaluate the strengths and weaknesses of this measure of winged insect abundance. The most abundant ant species (*Formica obscuripes*) in pine plantations is being researched with respect to territoriality and predatory behavior. Activity patterns are measured by an actograph constructed to observe effects of temperature, light intensity and humidity. Technical keys have been compiled on Michigan springtails as one of the most abundant animals in forest litter. These make possible research at a species level on side-effects of pesticide use and humification processes.

University of
WISCONSIN 1263

Population of dynamics of sawflies associated with coniferous plantations. Daniel M. Benjamin

Basic investigations on the sawfly *Neodiprion rugifrons* are aimed at clarifying the larval feeding behavior and the influence of the age of needles of jack pine on larval survival and adult fecundity. Prior studies showed that first generation larvae feed on needles one or more seasons old; however in the second generation, larvae also included current season's foliage in their diet.

First generation larvae showed strong preference for the old foliage. When they were offered only current or new foliage, its unsuitability as food was reflected in the increased dispersal, length of larval development, and mortality, and in decreased female weight and fecundity. Also, the time required by newly enclosed larvae of the first generation to take their first bite into new foliage was $2\frac{1}{2}$ times longer than they required to begin feeding on older foliage. This suggests that larvae can distinguish between new and older foliage before they start feeding. Possibly the new needles possess physical characteristics that prevent acceptance by the young larvae.

In the second generation, larvae increased their acceptance of current needles until they fed upon needles of all ages; their survival rate increased 38 percent over that of the first generation.

Rejection of new needles in the feeding by sawfly larvae is maximum at the time of growth initiation. When this foliage is one season old, it achieves maximum acceptance. Morphological and chemical factors responsible for this alteration in needle acceptability will be sought in this continuing research program.

University of
PUERTO RICO 3

Ecological relationship, distribution and control of two important species of arboreal termites.

S. Medina-Gaud

Investigations on the geographic and ecological distribution of the arboreal termites *Nasutitermes costalis* and *Nasutitermes nigriceps* are almost completed. The first species has been recorded in 146 different host trees, the second from 105. New areas were examined this year in the south and southwestern zones of Puerto Rico and on Desecheo Island. No termite species were found in our first survey on Desecheo. Field experiments using concentrated emulsions of DDT, Aldrin, Dieldrin, and Heptachlor are in progress. Each insecticide was used in concentrations of 1 part of the emulsion to 50, 100, and 150 parts of water applied as a spray to the termite nest and tunnels found on the trunks and branches of the trees. The concentration of one part to 100 parts has proved so far to be the most effective in termite control. All the insecticides except DDT were excellent in suppressing termite colonies and avoiding reinfestation for a period of about 6 months after the nest and tunnels are treated. Unless the nest is treated by applying the insecticide only to the termite tunnels, reinfestation is apt to occur in less than 2 or 3 months. Based on these findings, the use of the effective insecticides at the best concentration has been recommended for arboreal termite control to farmers and land managers. Use of this recommendation will contribute to the preservation of our flora and to the beautification of the Island by keeping the shrubs, trees and fences free of the undesirable termite nests.

University of
WASHINGTON 5

Motor responses of forest insects to environmental stimuli.
Herman J. Heikkinen.

This project was terminated with a report: The major environmental stimuli affecting the Douglas-fir beetle and the Sitka spruce weevil were defined, and the order of their relative importance on the behavior of these two species were qualitatively determined. The adult Douglas-fir beetle is definitely attracted by substances occurring naturally in its host tree. The substances have been identified as monoterpenes. The attack patterns of this beetle have been correlated with the order of attractiveness of individual terpenes and their occurrences in different parts of the tree.

The responses of the Douglas-fir beetle to olfactory stimuli are conditioned by primary responses to temperature, light intensity, wind speed and direction. Laboratory studies indicated that temperature is critical to initiation and continuance of insect locomotion, with major activity beginning at about 15°C and flight occurring at between 22-26°C.

OTHER PROJECTS

University of ARKANSAS 656. *Significance of Ips bark beetles and associated fungi in causing death of pines in Arkansas.*

William C. Yearian, Charles L. Wilson.

University of ARKANSAS 662. *Control of insects affecting seed production of loblolly and shortleaf pines in Arkansas.*

William C. Yearian.

University of GEORGIA 18. *Investigations of insects affecting pine cones and seeds in the Georgia Piedmont.*

Rudolph T. Franklin.

University of MAINE 5007. *Biology and control of the balsam gall midge.*

Eben A. Osgood, Jr.

University of MARYLAND H-83. *Biology and control of loblolly pine cone insects.*

W. E. Bickley.

MICHIGAN Technological University 8. *Basic studies on the insect transmission of scleroderris canker.*

Norman F. Sloan.

Beetle movement at temperatures below those causing flight is photo-negative at normal light levels, but photo-positive at light intensities of 70-100 foot candles. This correlates well with observations of beetle activity in forest stands where light intensity determines the points of concentration and the time of day of beetle activity, e.g., shaded areas, under heavy crown canopies, late afternoon and evening. Beetle activity is strongly influenced by air movement. Tests were conducted at controlled temperatures, and jet velocities of air stream. Beetles show a great variation in their exact response to this stimulus, and the response may be conditioned by the physiologic state of the individual beetle, or other factors.

The adult Sitka spruce weevil, when tested under laboratory conditions, showed an overwhelming negative geotaxis. Light intensity, temperature and wind movement had no discernible effect during the course of these experiments. When weevils were placed on a temperature-controlled vertical rod, the weevils went immediately to the top of the rod regardless of the temperature.

University of MICHIGAN 2. *The comparative natural histories of three closely related beetles of the genus Agrilus.*

Fred B. Knight.

University of MICHIGAN 14. *Population regulation in Oberea schaumii Lec. and Saperda concolor Lec. infesting trembling aspen suckers.*

Fred B. Knight.

MISSISSIPPI State University 1129. *Study of economic insects attacking certain forest tree seeds and forest seedlings.*

William W. Neel.

University of MONTANA 1604. *Effect of stand composition on spruce bud worm damage.*

William R. Pierce, David Fauss.

University of NEW HAMPSHIRE 4. *The ecology of the oribated mites and springtails of the soils of the white pine cover type in New Hampshire.*

R. Marcell Reeves.

NEW MEXICO State University 4. *Seed and cone insects of forest tree species.*

H. G. Kinzer, J. G. Watts.

OHIO State University 3. *Integrated control of the insect and mite pests of pine trees.*

R. B. Neiswander.

OKLAHOMA State University 1235. *Bionomics, ecology and control of the Nantucket pine tip moth.*

R. D. Eikenbary, Clayton E. Posey.

OREGON State University 824. *Biology of the Hemlock hylesinus.*

William P. Nagel.

University of PUERTO RICO 2. *Biology and control of the cedar shoot-borer.*

L. F. Martorell.

TEXAS A&M University 1525. *Development of diets and rearing methods for southern pine beetle.*

Neil H. Anderson.

University of VERMONT 2. *Effect of leader damage on growth of planted conifers.*

Terry L. Turner, W. R. Adams.

University of WASHINGTON 6. *Studies of the ecological and physiological characteristics of Pacific Northwest tree species.*

David R. M. Scott.

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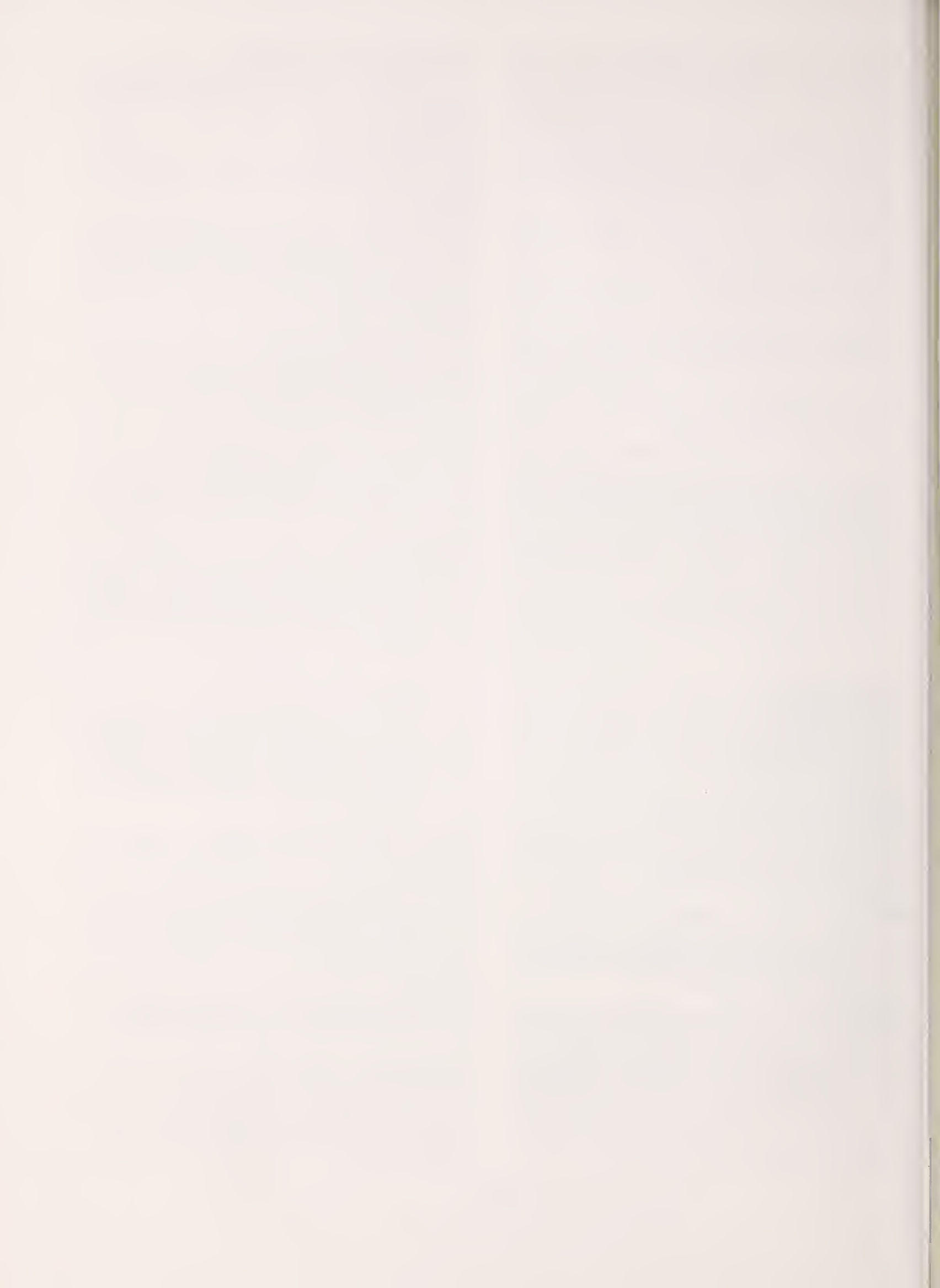
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Forest Management

A wide variety of research projects are to be found under silviculture, timber management, recreation, range, wildlife, watershed, and multiple use. The current research reflects advances in techniques that permit a progressively higher degree of quantification, and increased dependence on fundamentals of chemistry, mathematics, and physics as well as the biological sciences. Accordingly the results of these research projects should make more dependable and substantive contributions to advanced knowledge. The population pressure brings increased emphasis on multiple uses of public and private lands. Multiple use concepts are additionally stimulated by activated interest in air and water pollution.

SILVICULTURE

Auburn University
ALABAMA 908

Development of improved practices for nursery production of selected southern hardwoods.

Harry S. Larsen

Effects of the growth retardant B995 on height growth of yellow-poplar, American sycamore, and black tupelo seedlings in the nursery were tested. These hardwood seedlings typically become too tall in the nursery beds for economical handling and shipping, and effective ways of reducing height without reducing vigor are needed. Four rates of chemical concentration were tested in one versus two applications. Seedling height was significantly reduced by all treatments, without a reduction of root collar diameter. The highest chemical concentration applied twice proved most effective. This treatment reduced height of yellow-poplar and American sycamore seedlings 50% and black tupelo seedlings 25%. Outplanting tests revealed no significant effects of the chemical on survival or growth of any species during the first year outplanted in the field.

Two degrees of top-pruning after lifting are being tested on yellow-poplar and American sycamore seedlings. The two degrees of pruning are one-half and three-quarters of original height. If pruning does not greatly reduce vigor and growth, the advantages of reduced seedling height in lifting, baling, shipping, and planting may outweigh the increased competitive problems of smaller

seedlings. First-year measurements from outplantings are encouraging. Seedlings of both species averaged nearly two-thirds the height of unpruned seedlings after one growing season for the three-quarter pruning, and were only slightly smaller than one-half pruned seedlings. Amount of new growth increased with degree of pruning and was 80% to 140% greater for three-quarter pruned seedlings of American sycamore and yellow-poplar, respectively. Growth measurements to be made in the winter of 1968 will show whether these trends continue for more than one year.

University of
GEORGIA 22

Fiber production under short-term rotations.

Claud L. Brown, Jack T. May

In 1966-67, three specific areas involving three soil series in Jackson and Wilkes County were cultivated, fertilized and planted. One-year-old seedlings of American sycamore, sweetgum and yellow-poplar were planted at spacings, in feet, of 1 x 4, 2 x 4, and 4 x 4, in one-fortieth acre plots that were cultivated during the growing season. See Figure 19. The basic design calls for 3 species, 3 spacings, 9 replications, and 3 areas for a total of 243 plots.

Survival and growth were closely related to size of the planting stock. Large planting stock will be used whenever available. The first harvest will be made at the end of the second or third growing season, followed by successive coppice rotations of 1, 2 and 3 years.



Figure 19. Staff Physiologist Reines checks thrift of American sycamore in August of first-year growth after planting as one-year seedlings in fibre production test. University of Georgia 22.

In 1967-68, the study was extended to include cooperation with Owens-Illinois and International Paper Company. Sites selected in Decatur and Brooks County were prepared for planting in the fall of 1967. Some plots will be watered with effluent from the paper mill. Plantings will be made during the winter.

A nursery site is needed to determine maximum fiber production under the most intensive systems of management, including irrigation and frequent fertilization and cultivation. Soils and foliage will be analyzed periodically to maintain relatively high levels of fertility.

University of
NEVADA 671

Artificially regenerating Jeffrey pine on the east slope of the Sierra Nevada. C. M. Skau

Among notable research that has been completed on the effects of antitranspirants, attention to their economic value for regenerating Jeffrey pine seedlings is notoriously lacking. The objective is to increase survival of seeding transplants, specifically to deter-

mine physiological effects of antitranspirants on seedlings at various levels of soil moisture and evaporative stress.

Presently, instrumentation of one hundred pine seedlings is near completion. (Figure 20) The equipment acquired for measurement and recording of data in process of installation includes: a) A semi-automatic, chopper stabilized component recording system for thermocouple sensing of sap velocity, b) a net radiometer and Honeywell recording system, c) dry bulb and dew point sensors for measurement of D.P.D. and Honeywell recording system, d) soil moisture and temperature

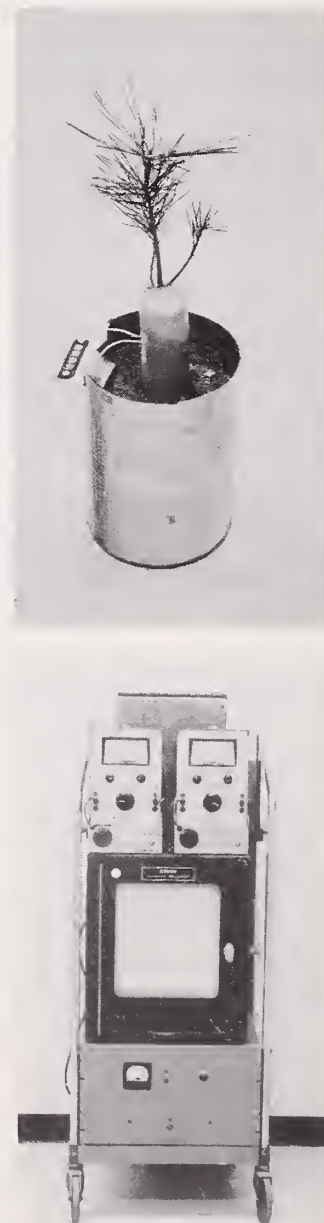


Figure 20. One of 100 Jeffrey pine instrumented for measurement of growing conditions in planting tests, and the recorder to be used for sensing sap velocity. University of Nevada 671.

probes and Honeywell recording system, and e) an infrared gas analyzer for measurement of net carbon dioxide consumption.

According to plan, 19 chemicals have been acquired; the remainder will be synthesized as needed. Initial testing of antitranspirants, beginning early in 1968, will eliminate all but five or six promising treatments. These treatments, in the spring of 1968, will be applied in the field to transplanted seedlings on harsh sites. Measurements will be made of percent survival, root growth, and shoot growth on both control and experimental plants for at least the first growing season.

University of
NEW HAMPSHIRE 1

A study of cultural practices for balsam fir Christmas tree production.
Paul E. Bruns

The techniques for large scale commercial application of cultural practices to produce a quality balsam fir Christmas tree on the regional market are becoming better understood. Mechanical cultural practices of initial shearing to shape the tree if needed, and clipping (current year growth only) of lateral branches to develop a fuller tree appear to promise greatest benefits. Now, field work on the project is completed to provide the data for statistical analysis.

Tip pruning to reduce leader or terminal growth and thereby avoid a spindly tree is now applied by commercial growers. However, observation on the research plots shows sufficient difficulty with formation of whorls so that recommendations may be modified as to the extent and perhaps time of year for this tip pruning. An alternative suggested by the results of fertilizer application may prove preferable-- to let the leader grow and stimulate internodal bud (the buds formed on the main stem) development through fertilizers. If sufficient internodal buds are formed and develop into branchlets to make the tree full, the time required to grow a Christmas of acceptable size might be shortened substantially.

In general, it appears that light applications of complete NPK fertilizer, or up to 2/5 pound for a 4-foot tree of nitrogen fertilizer, here in the form of ammonium nitrate, gives the desired results as to tree growth and color of foliage. However, heavier applications to this size tree may do more harm than good. Applications in May and early June result in good color for harvest in that fall. Then, in the next year the new foliage lightens. Possible recommendations may be to fertilize for color the spring before harvest, and fertilize for growth every other year.

Along with this, an attempt is being made through foliar analysis to describe the leaf nutrient content of average healthy balsam fir. By setting up appropriate standards, foliar analyses of sub-par trees might indicate directly what is missing from the growing site--in other words, the nature of the nutritional problem. From study of the plot data it appears difficult to correlate soil analysis and foliar analysis. For example, there seems to be little correlation between the number of pounds of potassium in the soil as indicated by soil analysis and the percent by weight of potassium in the tree needles.

University of
DELAWARE 759

Nutrition and management of woodland trees of ornamental value.
C. W. Dunham

Initial work on this project has attempted to develop sampling and analytical techniques for determining the nutritional status of American holly. The first year's nutrition data consisted of leaf analyses taken from leaves in different positions on the shoot at different times of the year. Leaf samples taken in April before growth started and from the same trees in October after growth had ceased had similar composition. When growth started in the late spring, mobile nutrients appeared to move out of last year's leaves and into the new leaves. During July the highest content of N, P, and K for the year were found in the new leaves and the lowest

content in the old leaves. This annual re-distribution of nutrients within the leaves of holly may account for the fact that the differences in mineral content of leaves from fertilized and unfertilized trees were not as great as expected. Further data needed include the effects of light intensity and of fruiting on nutrient re-distribution. Preliminary data have indicated that light intensity plays a major role in fruiting of American holly.

University of
NEBRASKA 20-23

Windbreak shelter effects.

Walter T. Bagley, Norman J. Rosenberg

Six windbreak systems are under test. After extensive land preparation involving tree removal and waterway construction, trees were planted in the spring of 1966. Trees are spaced 6 to 8 feet apart in the row, and will be subject to thinning. First-year survival and growth of trees in the windbreaks has proved excellent. Three systems are designed to attain moderate density; the other three to provide low density windbreaks early in the life of the planting, and high density in later years. The moderate density pattern has two rows of eastern redcedar, R, green ash, a, and Austrian pine, P, planted as follows:

R a R a R a R a R a

a a P P a a P P a a

The combination low-and-high density pattern consists of: cottonwood, C, eastern redcedar, r, and Scotch pine, S, planted as follows:

C r C r C r C r C r

r r S S r r S S r r

The windbreak pattern used has parallel strips 1,350 feet long, spaced 450 feet apart that intersect to make a tic-tac-toe pattern. This provides nine square 4-acre fields with shelter on 2, 3 or 4 sides. Nearby, 4-acre fields are established as unprotected con-

trols. Each field is divided into a grid of nine plots measuring 135 by 135 feet.

Concurrent with tree establishment, a uniform cropping system is being started for all fields in the windbreak system. The first year's uniformity tests were completed with the July 1967 harvest of wheat that provided yields on 473 one-half acre plots with supporting test weights and protein analyses. Studies were conducted in a sugar beet field protected by windbreaks on the supply in the atmosphere of carbon dioxide--the building material for all plant and animal life. The concentration of carbon dioxide in parts per million (ppm) followed a diurnal pattern of high at 350 ppm during the night and low at 260 ppm during a clear day. Compared with the open field, concentrations on sheltered plots between windbreaks reached a night level of 8 to 10 ppm higher. During the day, sheltered plots were 2 to 4 ppm lower, which would mean only a one percent decrease in photosynthetic use of the carbon dioxide. This indicates that the presence of windbreaks does not decrease the carbon dioxide supply enough to result in significant decrease in yield.

NORTH DAKOTA
State University 12-1

Establishment, maintenance and effects of shelterbelts in North Dakota. Edward P. Lana

Twenty years after cessation of cultivation, over 70 percent of the shelterbelts had an understory cover dominated by grasses. The production of understory vegetation, which averages over 1,400 pounds dry-weight per acre in older belts, indicates that serious competition exists between the tree growth and the understory vegetation. The evidence is clear that the shelterbelts will not be able to maintain themselves by natural reproduction over the years.

Attempts were made to evaluate damage and growth reduction of shelterbelt trees infested with pest insects. Currently, the populations of pest species proved to be at an endemic level and this damage was at a minimum. No serious infestations of any species were observed or reported.

Shelterbelt species were studied for effects of herbicide treatments. Retreatment of each half-plot was made identical to the previous year's treatment. Residual effects of the herbicide on the trees and weed population are being determined. Comparisons will be made between the residual and annually treated plots to determine herbicide recommendations in newly planted shelterbelts.

In the alkaline Fargo clay loam soil, ponderosa pine from the eastern Rocky Mountain slopes survived better than ponderosa pine from western Rocky Mountain slopes. Amendment of this soil with acidifying sulfur or sulfur plus peat moss significantly increased the survival of ponderosa pine planting stock having mycorrhizal roots. Trees without mycorrhizal roots failed to survive even with soil amendments.

SOUTH DAKOTA
State University 420

The establishment of tree plantings to enhance the recreation potential of selected sites on Missouri River reservoirs in South Dakota. Paul E. Collins

This project is directed toward improving the success and growth of trees on prairie sites adjacent to waters impounded by dams on the Missouri River. Here, most of the ingredients for recreational use are present except tree

growth; the natural flood plain tree species have for the most part been inundated by artificial lakes.

Primarily, the studies have been directed toward problems of establishing conifers on sloping sites (Figure 21). Five-foot contoured strips were chemically fallowed the year before planting. Eastern redcedar and ponderosa pine transplants were hand-planted in the median of the strips. Some of the fallowed strips were prepared by scalping and trees were planted in the furrow. Two-year survival of Eastern redcedar was good in all treatments; ponderosa pine survival was generally low, a common occurrence in this species. Soil moisture patterns throughout the growing season suggested that furrowing was beneficial on loess soils underlain with sandy material. On heavy soils underlain with clay, furrowing exposed a less hospitable soil medium for moisture retention.

In 1967, 5,000 Eastern redcedar and ponderosa pine transplants were machine planted on a site of the left bank of the area above the Big Bend Dam to determine the influence of slope and aspect on survival. The site was prepared by furrowing alone. First-year results indicate best survival of conifers on north slopes.



Figure 21. Testing site preparation for tree planting that margins the Missouri River impoundment above Big Bend Dam. Left: Project forester Jensen reads soil moisture by neutron probe in chemically fallowed five-foot tree planting strip. Right: Mechanically scalped strip planted to ponderosa pine.

It appears that research now underway will contribute substantially to afforestation along the large reservoirs in South Dakota. Trees

are essential to develop the full recreational potential of these large inland lakes.

OTHER PROJECTS

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C. L. Brown.

Southern ILLINOIS University 64-R-42. *Hardwood planting on upland old-fields in southern Illinois.*
Carl Budelsky.

Southern ILLINOIS University 67-R-14. *A study of the suitability of selected native trees for use in parks and recreation areas in Illinois, Indiana, and Ohio.*
Dwight R. McCurdy.

INDIANA - Purdue University 1476. *Establishment of improved selections of certain forest trees.*
William R. Byrnes.

KANSAS State University 668. *Windbreak investigations.*
Paul L. Roth.

KANSAS State University 672. *Christmas tree production.*
Paul L. Roth.

KANSAS State University 721. *Procedures and techniques designed to revegetate strip mined lands of southeastern Kansas.*
Wayne A. Geyer.

LOUISIANA State University 1237. *Producing and marketing Christmas trees in Louisiana.*
Benton H. Box.

MICHIGAN Technological University 11. *Distribution patterns of eastern hemlock reproduction.*
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University of MINNESOTA 19-16. *Environmental factors related to the failure of red pine reproduction.*
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University of NEVADA 674. *Survival of grass and tree species of high elevation in the Sierra Nevada.*
C. M. Skau.

NORTH CAROLINA State University 4011. *Variation in early development of sweetgum seedlings with changes in (a) soil nutrient regimes and (b) female parentage.*
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NORTH CAROLINA State University 4013. *A study of the taxonomy, distribution, and ecology of Carolina shagbark hickory.*

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OKLAHOMA State University 1360. *Control of undesirable woody plants: effect on forest and native grass development and wildlife.*

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C. F. Sutherland.

PENNSYLVANIA State University 1745. *Revegetation of highly adverse sites created by coal mining.*

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University of TENNESSEE 1. *Growth of mixed species plantations.*

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Eyvind Thor.

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TIMBER MANAGEMENT

University of
CALIFORNIA 2447

Financially optimum thinning regimes for young-growth, mixed-conifer forests of California.

Rudolf F. Grah

The task of identifying the most favorable thinning regimes for California young-growth stands has been approached in this project by using Monterey pine. This native species is one of the fastest growing conifers in the world that has received more management attention overseas than in the U.S. Abundant growth and yield information on this species enabled the development of realistic models of economic performance of intensively managed stands, and, through the use of these models, to identify the important financial variables in thinning regimes. Results of this study will guide work with mixed conifer stands. Findings indicate that at low interest rates, (3%), a single thinning which comes early in the rotation is more profitable than frequent later thinnings. At higher interest rates, (6 and 9%), the situation is reversed and regimes with multiple commercial cuts later in the rotation are more profitable. At the highest interest rate, (9%), the growing of unthinned stands was not a profitable undertaking; all thinned models studied yielded sufficient returns to cover all costs with interest as well as yielding rent to the enterprise. The study also indicates that maximum profitability depends on maintaining short rotations of 40 years or less for Monterey pine.

University of
GEORGIA 19

Relationships between site and growth of swamp and water tupelo.

Jack T. May

Private citizens and corporations commonly own forest land to obtain economic gain, and the decisions involved in management of such holdings are made with this objective in mind. In order to maintain ownership of the land, a

private owner must pay property taxes. In addition, if he receives economic gain, payment of federal income tax is indicated. Hence, any forest management decision-making process should consider the pertinent tax implications associated with the possible courses of action. It is the objective of this project to mathematically express some important forestry decision problems and quantitatively evaluate the effects of tax considerations on the solutions to these problems. Such evaluations should be of interest not only to taxpayers wishing to maximize personal or corporate economic gain but also to public officials charged with enacting and interpreting tax legislation with the objective of maximizing benefits to society as a whole.

Major attention has been devoted to investigating the effects of various federal tax systems on optimum cutting ages in even-aged stands of southern pine. The specific systems considered to date are:

- a) No federal taxes considered.
- b) Stumpage income taxed as a long-term capital gain; planting costs capitalized.
- c) Stumpage income taxed as a long-term capital gain; planting costs treated as an ordinary expense.
- d) Stumpage income taxed as ordinary income; planting cost capitalized.
- e) Stumpage income taxed as ordinary income; planting costs treated as an ordinary expense.

Analyses of these systems indicate the variations materially affect the present value of forestry enterprises, and certain operations which would be profit-making under some systems would not be sound investments under others. However, where an operation would be profitable under all systems, the optimum cutting practices are essentially

the same for all taxation systems considered.

The influence of per cord depletion rate on optimum cutting practices has also been investigated. Results of this analysis indicate that cutting decisions can be significantly influenced by the depletion rate and that recognition of this fact is of considerable importance in manipulating cash flows. However, such manipulation is, in general, feasible only when depletion is calculated on a tract rather than a block basis. Current effort in the project is aimed toward evaluating the influence of federal taxation systems on timberland lease and timber purchase agreement decisions. Detailed analyses of various local tax systems are also planned for the near future.

Humboldt State College
CALIFORNIA 4

Productivity of certain hardwood species in Humboldt County, California.

William S. Berry, H. V. Wiant, Jr.

The following status is reported on the development of tariff numbers and volume tables for hardwood species in the redwood region: a) Tanoak, completed in 1966; b) Pacific madrone, field data collected in 1966 awaits adjustment for forking of stems; and c) Golden chinquapin, of interest to industry.

LOUISIANA
Polytechnic Institute 1

Forestry yield data from responses to thinnings of natural even-aged stands of loblolly pine.

Edward R. Andrulot

Since establishment of the Urania-Chapman plots at Urania, Louisiana, in 1930-31 they have been periodically remeasured by the late Professor H. H. Chapman and students of Yale Forest School, maintained by Glen F. Tannehill of the Urania Lumber Company, and remeasured by Professor Lloyd P. Blackwell and students of Louisiana Tech.

Originally, eight pairs of plots were installed in 17-year-old natural stands of loblolly pine. The objective was to compare growth and yield between managed, thinned and unthinned stands. At stand age 35, in 1948, five of the eight control plots were entered on a program of cutting which offered a third treatment designated as delayed thinning (Figure 22). Measurements were made at approximately five year intervals and consisted of DBH, total height, and live crown length. In-growth was noted and brush was controlled on selected plots. Analyses of data from all these plots are through stand age 50. There were significant differences in size, quality, and mortality according to amount of thinning. The most intensive thinning left 72 trees per acre for the final crop. Correlation between soil, rainfall, stand density, and other factors with growth and development are in progress.

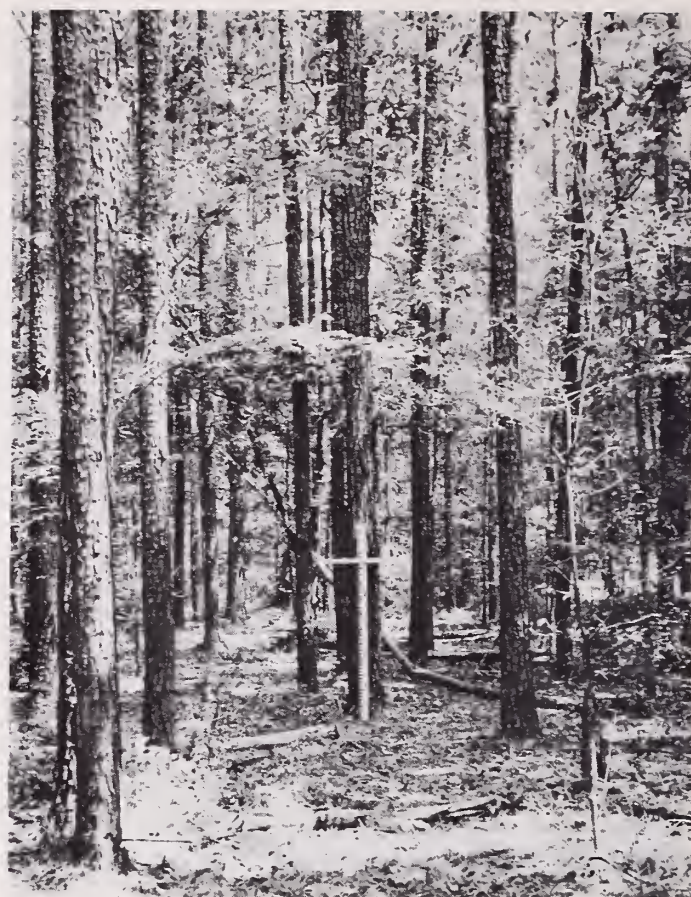


Figure 22. Views in summer 1966 of loblolly pine on plots established in 1931 by the late Professor H. H. Chapman and Yale Forestry School students in natural 17-year-old pine stands of Urania Lumber Company. Measurements at the planned 50-year maturity showed increased growth and yield from management. *Above:* Plot 11 was not thinned. Pine yield is 51.1 rough cords, with hardwoods in mixture bringing total basal area to 170 square feet per acre. *Top Left:* Plot 2 was treated by "delayed thinning" started at age 35. Pine yield is 61.5 rough cords per acre; with light hardwood brush the basal area totals 213 square feet. *Lower Left:* Plot 7 was thinned every 5 years from age 23 to 43. Pine yield is 61.6 rough cords; with dense hardwood brush, the basal area totals 194 square feet. Louisiana Polytechnic Institute 1.

OKLAHOMA
State University 1247

Tree stem frequency distribution. Nat Walker

Further effort has aimed at identifying the types of frequency distributions obtained for trees in successive 2" diameter classes. It now appears that the frequency distributions of trees from the 6" to the 20" classes are best defined by the negative binomial distribution.

A number of tests for quantification of contagion have been used: a) The variance/mean ratio where values greater than 1 indicate contagious distributions; b) the parameter of the negative binomial series, where low values for k indicate a high degree of contagion, and c) Charlier's coefficient of contagion "C". All timber types studied, except Appalachian hardwoods, show contagious distributions in the smaller size classes, and more nearly random distributions for larger size classes of 22" and larger diameters.

Association or contingency (contagion) between size classes has been studied in joint frequency tables, where the frequency of occurrence of one size class with each other size class was evaluated. Two tests were devised for joint frequency tables. First, the correlation coefficients were obtained and analyzed; secondly, four-fold contingency tables were tested by chi-square. The methods give similar results of strong correlations between small trees such as 6" with 8", or 6" with 10", but not between small and large classes. Contingency exists between 14" and 16" trees, but not between 14" and 26", or 14" and 6". Likewise, adjacent large diameters, such as 24" and 26", show positive correlation. The tendency for this type of clumpy and contagious distribution of stems casts some doubt upon our presently accepted methods of systematic and random sampling, by either fixed-radius plots, or by polyareal plot methods.

University of
WEST VIRGINIA - 5

Growth and yield of West Virginia hardwoods as affected by stand density and site quality.

Don L. Kulow

During the past year, the data from 136 permanent field plots have been transferred to magnetic tape for compilation and analysis. Special programs have been written for the IBM-7040/44 computer to aid in this study. The following information is now available: a) standard volume table equations, b) local volume table relationships between height and diameter, c) site index curves, d) stock and stand tables, e) projected growth, f) accumulated growth, and g) accumulated yield. The accumulated growth and the accumulated yield data are being tested against a number of linear models for best fit and compatibility. The resulting equation will indicate an appropriate model for determining yield information from growth data in this area. The plots have been thinned to simulate management conditions and during the next year, remeasurement of these plots will begin.

University of
GEORGIA 16

Relationships between site and growth of swamp and water tupelo.

Jack T. May

The study was confined to a 100-acre swamp in the middle Coastal Plain of South Carolina. The swamp was stratified into the head, the run and fingers and outlets, and extensive sampling of soil, water, and trees has yielded much useful information. Water and swamp tupelo are the dominant species present. (Figure 23). Both swamp and water tupelo produce false rings. Sweetgum and red maple are the only other species that occur to any significant extent in the swamp. The depth of the water table proved positively correlated with cubic-foot volume, board-foot volume, basal area, height of the dominant and co-dominant trees, and average annual growth.



Figure 23. Tupelo gum on one of the 60 study plots in the South Carolina Coastal Plain swamp. University of Georgia 16.

Analysis of results has yielded useful inferences for the prediction of site for tupelo. Three measures of productivity of tupelo on which prediction proved meaningful are basal area, board-foot volume, and cubic-volume. Prediction was also useful for cubic volume over age, tree height, and site index of tupelo. Variables are arrayed by their overall value as predictors of the measures of productivity:

- | | |
|------------------------------|--------------|
| a) stand density | e) iron |
| b) reciprocal of age | f) manganese |
| c) age of the best site tree | g) zinc |
| d) magnesium | h) soil pH |

The first three of these are familiar factors in estimation of productivity. It is quite unexpected to find the minor mineral nutrients magnesium, iron, manganese, zinc, (and even soil acidity) as critical factors in prediction of site productivity.

UTAH
State University 659

Evaluation of the relationship of site index to periodic annual increment of uneven-aged Engelmann spruce-subalpine fir stand on the Utah State University Forest.

Raymond R. Moore

A multiple regression equation was developed from data obtained from 54 permanent sample plots established in 1950 and remeasured in

1964. The dependent variable was gross annual volume increase per acre for trees 5.0" DBH and larger, and independent variables were site index and specific forest stand descriptive characteristics. The multiple regression equation developed from the data accounted for 79 percent (R^2) of the total variance in gross increment.

The influence of site index as an independent variable was estimated by means of the stepwise regression analysis. Also, three separate site index tables were used for determination of site index for each of the plots. The local tables, prepared specifically for the Engelmann spruce stands on the University Forest, gave the largest R^2 value to the regression equation. The new tables prepared for the Intermountain Region by the U.S. Forest Service were almost equally as good.

The effectiveness of site index as a single independent variable was found to be very small. This indicates site index, although generally accepted as a good measure of relative productivity, is not responsive when compared to variables describing the forest stand characteristics. However, when combined with other stand variables, such as basal area, site index proved to be a significant combined variable.

University of
CALIFORNIA 2180

Multiband spectral reconnaissance for forestry purposes.
Robert Neil Colwell

This project seeks to discover ways in which aerial photography and related imagery obtained from several wavelength bands of the electromagnetic spectrum can be employed to advantage for forestry purposes. During the period reported, multiband reconnaissance studies were concentrated on two areas: a) The Harvey Valley Experimental Range, a facility of the Pacific Southwest Forest and Range Experiment Station located near Mt. Lassen, and b) The Meadow Valley-Bucks Lake Forestry Site located in the Sierra Nevada Mountains on the Plumas National Forest. In both instances multiband imagery was obtained at no cost to this project.

In the Harvey Valley area, imagery from a total of 12 bands was intensively studied to determine the ease and accuracy with which various rangeland vegetation types, soil types, and soil moisture conditions could be discerned on the multiband imagery. Of these 12 bands, five were in the visible portion of the electromagnetic spectrum, one in the ultra-violet, two in the near infrared, one intermediate between the near and far infrared, and three in the far infrared region. On each type of imagery, soil-vegetation boundaries were drawn after which they were carefully field checked for accuracy. The conduct of these studies indicated the following conclusions:

- a) Most of the significant soil-vegetation types can best be discerned on the spectral bands sensitive to red wavelengths of radiant energy in the visible part of the electromagnetic spectrum. Therefore, this band is judged to be the most useful single band of the many studied.
- b) Dense, lush grass and meadow vegetation is most readily distinguished from all other features on one of the near infrared bands.
- c) Moisture regimes where springs, wet soil, and marsh vegetation obscure standing water beneath are best imaged on the 8.0 - 14.0 micron band.
- d) An occasional soil-vegetation is best seen on the ultraviolet band.
- e) Obviously, more complete range resource information results from a multiband reconnaissance system than from any single band system.

MICHIGAN
Technological University 3

Standard computer program for continuous forest inventory analysis.
James W. Meter

Scientific management of the forest requires that specialized knowledge be developed on forest stands, the volumes of wood being grown, and the changes taking place with the

passage of time. These are no simple matters to calculate for large acreages of forest that may spread over several counties. Over the past 20 years a large number of private forest (as well as public and research forest) operators have adopted the procedures known as CFI, or Continuous Forest Inventory, to develop data for management control, planning, and policy making purposes. Tree records are collected on punch cards from permanent sampling stations. These samples are scattered throughout the forest to represent the various collections of soils, tree stands, and forest cover. Repeat measurement of the same trees on the same samples at recurring periods of 3-5 years provides an excellent record of the growth of wood volume, of mortality, and of the effects of cutting, weather, insects, and disease.

This project deals with the computer analysis of CFI data which was recognized (by a recent conference held at our Ford Forestry Center) as a bottleneck in need of standardized computational procedures. Now there are a score of industrial CFI cases in the North Central States involving analysis and control for some 8 million acres of forest land under scientific management. The large size and complexity of the computational task directed that the program be broken up into several segments, designed for the high-speed electronic computer operation with data storage and blocks of core "memory."

To date, four major program segments are complete, with one major and one minor block still unfinished. These segments for data editing and error correction, for volume and growth computation, and for basic forest analysis have been tested on 5 industrial cases, and our own research forest. Because of pressure for early use of these available segments, we decided to delay completion of the basic program in favor of extending mutually beneficial applications of the program to forest industries. Obviously industry is according the program excellent reception.

The remaining work on this project includes a) the scheduled early completion of two segments of the program, b) the documentation and description of the program opera-

tion, c) preparation of easy-to-understand instructions for its use, and d) publication and distribution of the program for processing of Continuous Forest Inventory data.

State College of Forestry
at Syracuse University
NEW YORK 1

Investigation of sampling systems and standards appropriate to an inventory of forest resources under various forest conditions to meet a variety of owner needs in a number of socio-economic environments.

C. Allen Bickford

Photogrammetric measurements of several stand variables were made on over 200 forest survey plots in Central New York to provide means and variances for subsequent simulation studies. Computer programs were developed to introduce photogrammetric techniques into the study. A stem map of 10 acres of the Heiberg Forest has been prepared to provide estimates of various parameters of tree distributions and to provide a population for trying out various sampling possibilities. This stem map will serve for a thesis problem proposed to compare selected sampling alternatives with computer simulation.

Plans for the coming year call for collating forest survey data and related photogrammetric measurements to identify superior uses of aerial photographs in forest inventory. Other research aims at developing and integrating procedures for stands described by varying densities and d'Liocourt's quotients.

INDIANA - Purdue University 1352.

Introduction of central hardwood forestry activities into mathematical programming systems for farm planning.

Otis F. Hall

Upon termination this year, all objectives of the project had been achieved. Special ways of structuring the linear programming matrix were developing to permit incorporation of the usual one-year farm planning model in the same matrix as a 33-year forest planning model. The model gave meaningful results with real data from typical control Indiana

farms and forests. Even on a highly profitable corn-hog farm in Central Indiana, timber stand improvement and woodland harvesting activities were included in the plan for optimum allocation of farm labor to maximize profit of the entire enterprise. At the highest interest rate tested, 6% woodland activities were still included, but at slightly less labor-intensive jobs.

Purdue University
INDIANA 1357.

Developing yield function's for uneven-aged forest stands.
Otis F. Hall, John W. Moser, Jr.,
Peter E. Dress, Thomas W. Beers.

This project has been terminated with the following report: The research has made a

OTHER PROJECTS

ALABAMA - Auburn University 909. *Effectiveness of standardized forest condition classes for aerial photographic forest inventory.*
Evert W. Johnson.

Northern ARIZONA University 1. *A comparison of measures of stand density for ponderosa pine in the southwest.*
Charles O. Minor.

University of CALIFORNIA 2349. *Determination of optimum forest production schedules by mathematical programming.*
Dennis E. Teeguarden.

University of CALIFORNIA 2520. *Mathematical simulation of forest stands.*
Lee C. Wensel.

COLORADO State University 317. *Soil-site relationships in lodgepole pine stands in northern Colorado and southern Wyoming.*
Edward W. Mogren.

University of FLORIDA 1130. *Correlation of soil survey information with tree growth.*
Clemens M. Kaufman, W. L. Pritchett.

University of GEORGIA 21. *Prediction of growth and yield in artificially regenerated stands of loblolly and slash pine.*
Jerome L. Clutter.

INDIANA - Purdue University 1586. *Data processing for small woodland management.*
John W. Moser, Jr.

major contribution by clearly describing the way forest yield equations may be developed from growth measurements on permanent plots. It has been shown that growth can be expressed as differential equations, and that these can be integrated to give a yield function. In uneven-aged stands, elapsed time between measurements can be used instead of stand age to give the variable for integration. The theoretical method has been tested on data from actual plot measurements over a period of 18 years, to give a yield function that can be used to estimate the yield from this stand at any age in the future. As a valuable outgrowth of the project it has been shown that computer programs for non-linear regression can much improve the fit of growth curves to raw data coming from permanent plots.

LOUISIANA State University 1266. *Measuring competition in even-aged pine plantations.*
Thomas D. Keister.

MICHIGAN State University 978. *Financial evaluation of forest management opportunities.*
Victor J. Rudolph.

University of MINNESOTA 19-38. *Application of computer technology and o.r. techniques to forest inventory and management.*
Hugo H. John.

University of MINNESOTA 19-79. *The ecological foundations of forest production in Minnesota.*
Egolf V. Bakuzis.

MISSISSIPPI State University 1120. *The relationships of certain tree and stand variables to stem form.*
Roy D. Ross.

NEW MEXICO State University 3. *Management practices on forest lands in New Mexico.*
James R. Gray.

NEW MEXICO State University 5. *Soil-site requirements for ponderosa pine.*
A. G. Wollum, II.

NORTH CAROLINA State University 4014. *Least squares estimation of the parameters in some non-linear models to describe tree growth.*
W. L. Hafley.

OKLAHOMA State University 1236. *Development of aerial volume tables for central Oklahoma mixed hardwoods.*
David W. Robinson.

- OKLAHOMA State University 1237. *Factors related to tree mortality or survival in commercial timber types in Oklahoma Ouachita Highlands.*
T. H. Silker.
- OREGON State University 822. *Tree volume by height accumulation.* D. P. Paine.
- OREGON State University 823. *Effect of spatial distribution on sample variance.* D. P. Paine.
- PENNSYLVANIA State University 1493. *Soil site evaluation for black cherry and associated major species.* W. W. Ward.
- SOUTH CAROLINA - Clemson University 706. *Timing of harvest in even-aged timber stands.*
John R. Warner.
- University of TENNESSEE 4. *Determinants of forest management intensity.* Garland R. Wells.
- University of VERMONT 4. *Volume equations for major trees of Vermont.* Luther E. Zai.
- University of VERMONT 8. *Growth and wood quality of yellow birch.* Peter R. Hannah.
- VIRGINIA Polytechnic Institute 31. *Parameters of site for certain tree species in Virginia.*
H. A. I. Madgwick, R. Stemple, J. F. Hosner.
- VIRGINIA Polytechnic Institute 51. *Periodic growth of mixed hardwoods in the southern Appalachians.* James P. Barrett.
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RECREATION

IOWA

State University 1580

Forest-recreation investment opportunities in Iowa.

Henry H. Webster

This project is designed to estimate the relative values Iowans place on various kinds of outdoor recreation, and to provide a base for developing trend estimates from future surveys. These estimates are currently being used by state agencies in development of plans for expanded and improved recreational facilities.

Interviews were carried out during the fall of 1966, measuring recreational participation during the preceding year, and statistical compilations have been made of resultant data.

Driving for pleasure is the most popular away-from-home outdoor recreation activity of Iowans, in terms of both numbers of people involved and time devoted to this activity. Other notably popular activities were picnicking, walking for pleasure, and sightseeing. During the study period, more than half the residents of Iowa participated in each of these; and between one-third and one-half also attended outdoor sports, fished, played outdoor games, swam, and boated.

These results show that Iowans' outdoor recreation activities differ significantly from rates for residents of the North Central region (as defined in surveys by the Outdoor Recreation Resource Review Commission). More Iowans drive for pleasure, attend outdoor concerts and plays, go sightseeing, bicycling, fishing, picnicking, horseback riding, and camping than is the case for residents of the North Central region as a whole.

University of

MINNESOTA 19-77

Ecological implications of the management of Itasca State Park to meet recreational objectives.

Henry L. Hansen

During recent years the protectionist philosophy in the management of park and

recreational areas has been under critical review. That undesirable ecological consequences may result from pure, immutable protection-management has been predicted by foresters, wildlife managers, and ecologists in increasing numbers. This project, with its aim of orienting ecological research to the problems of managing the forested recreational areas of Itasca State Park, has amassed considerable information which documents some harmful results of dogmatic protection-management.

The park was created in 1891 to include the headwaters of the Mississippi River and to perpetuate the stands of virgin red and white pines. The prime importance of these pine stands as a present recreation attraction was shown in the results of a visitor reaction survey conducted in this study. Photogrammetric analyses of aerial maps indicate a serious imbalance in the current acreage and age distribution of these pine stands. There was a critically inadequate acreage of young pine stands coming along to replace the old trees that are being decimated by wind and other destructive agents at an accelerating rate.

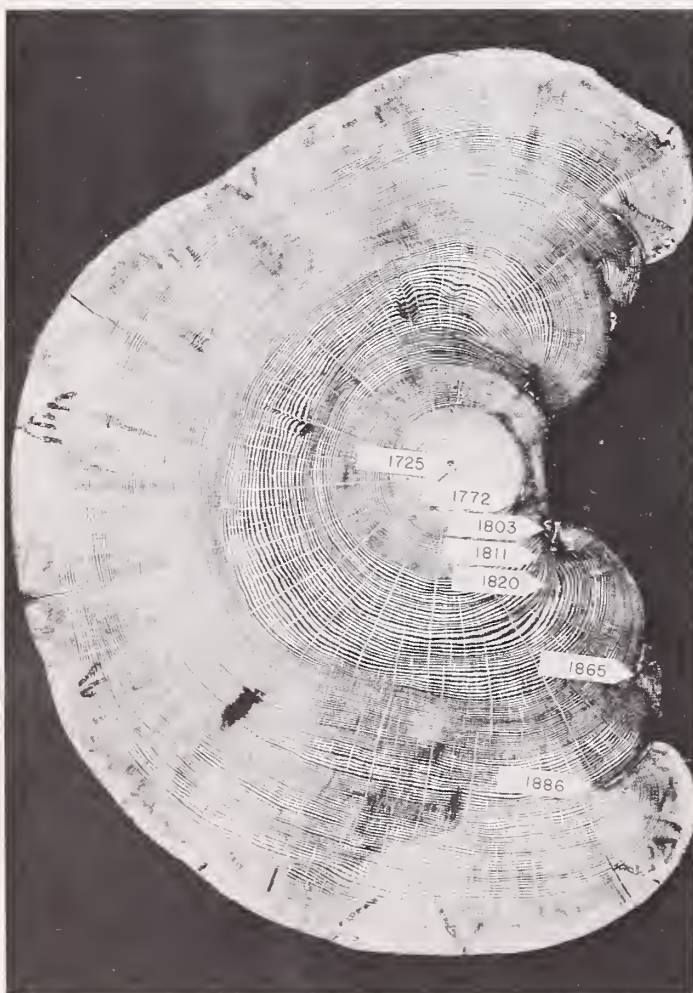
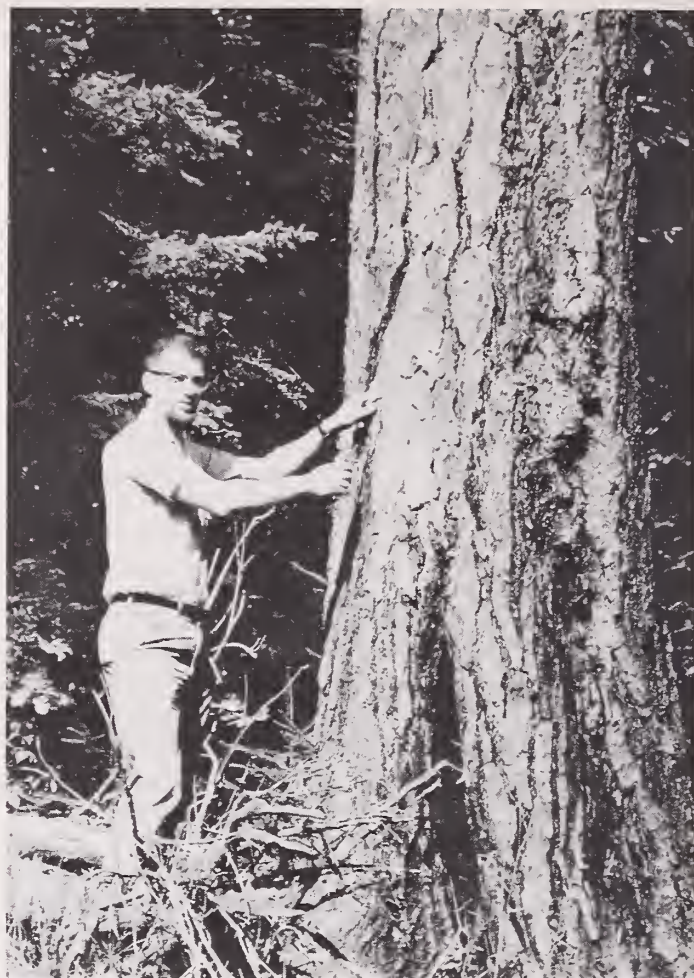
The ecological analyses reveal that the pine cannot compete with the heavy brush canopy. Pine persists only on the very dry sandy sites where hardwood brush is almost absent. Analysis of fire scars and aging of over 3,000 individual trees indicates that the existing pine stands followed the forest fires which were common in the pre-park years (Figure 24). These increment cores provide a wealth of information relating tree growth to past weather patterns, insect attacks, and other aspects of historical interest. Curious restrictions noted in the growth of pines from 1863 to 1917 are as yet unexplained. Trees have been discovered which are larger or older than any previously reported for several species. The country's largest red pine was discovered near Lake Itasca. Several bur oaks dating back to 1619 are much the oldest on record. Another bur oak with 331 sound annual rings plus five inches radius of rotten wood is estimated at over 400 years old.

Figure 24. Red pine focuses recreationist interest in Itasca State Park headwaters of the Mississippi River. University of Minnesota 1977.

A. Section of red pine with annual rings documenting the tree's growth through 242 years. Distinct scars, as flagged by year, record six historic fires survived before the decay-weakened veteran succumbed to storms in recent years.

B. This veteran discovered still growing with 37.5-inch DBH and 124-foot height, here rechecked by Sidney Frissell, is the largest red pine in the country.

C. Under the red pine stand undisturbed at 155-year maturity, typical heavy shrub canopy obstructs any regeneration of red pine.



Reliable age counts on several red pine dating them over 300 years old have extended the reported longevity of this species.

The project has contributed information of considerable interest in dendrochronology, pollen stratigraphy, and archaeology. Results of this project are significant not only to Itasca State Park but also to many other national and state parks and recreation areas where subclimax forest types of the aesthetically preferred pines are present. The research goal of major concern here is to develop silvicultural methods to secure pine regeneration in the absence of uncontrolled wildfire. Application of herbicides has already been found to be helpful toward this. Further tests involving rigorously prescribed burns, carefully controlled logging, planting and seeding are featured in future research plans.

University of
MARYLAND T-16

An analysis of the factors affecting the status of private forest recreation development in Garrett County, Maryland.
V. R. Cardozier

This study, in Maryland's far western Garrett County which is mountainous and moderately forest covered, reported considerable socioeconomic and behavioral data and preferences for about 2,500 non-resident property owners located both on the large Deep Creek Lake and in upland regions of the county. Lakeside property owners understandably made much heavier use of water recreation, while the upland owners used open area sports more heavily, particularly hunting and auto riding for recreation and scenic enjoyment. The uplanders also did more social visiting, but this is related to the fact that they had more family ties and visited more with relatives while in the county. Facility sports of skiing, golfing, camping, and horseback riding were comparatively low by both groups. Formal social activities were also low. This indicates a strong preference among both groups for outdoors activities of rich variety, with water sports predominating. When actual activities were compared to desires for in-

crease in recreation of various types the pattern as between water sports, outdoor facility sports, other open area sports, and both formal and informal social activities, it was found that increases desired were about 50 to 100 percent over the actual. It was remarkable that the pattern of the desired increases was almost identical to the present pattern of recreation, in relative levels of six functional groups, and for residents on Deep Creek and upland areas. This means that there was no striking frustration beyond a "more of the same" attitude, and it suggests that the pattern in this mountainous, forested water-rich county provided these 2,500 non-residents a high level of recreational satisfaction.

University of
TENNESSEE 5

Recreation resources of large private forest ownerships in Tennessee.
Kerry F. Schell

This study dealt with 96 ownerships over 5,000 acres that totaled 2,100,000 acres. Of these, 37 percent range from 20,000 to 100,000 acres, and 30 percent were ownerships over 100,000 acres. Field checks with owners or managers who were accessible turned up 85 usable observations. Some ownerships no longer existed, having passed into public or consolidated ownership. Others were under long-term lease to wood-using industry. A few were excluded as doubtful; a few were added to the list.

Inspection of the data reveals the following: a) The large private forest ownerships are heavily concentrated on the Cumberland Plateau and the Highland Rim. b) A small proportion of ownerships had professional forest management services, or had investments in timber production other than ownership of the forested land. The predominant cutting guide is diameter limit and species designation. c) Fire control has been the single, most important factor contributing to timber resource improvement in Tennessee. d) Most of the large forest ownerships are available for public recreation. Fire

danger and personal liability are most frequently offered as reasons for trespass restrictions. e) Currently, the major recreation use of these lands is hunting. f) There is virtually no development of the recreation resources of these lands. The most frequently offered reasons for nondevelopment are insufficient demand, user liability problems, uncertain returns and lack of capital and lack of technical knowledge.

LOUISIANA

State University 1177

The role of large private forest owners in outdoor recreation in Louisiana. Robert W. McDermid.

This study examined the present policies of owners of large tracts of private forest lands in Louisiana to determine the effect of these policies on public use for compatible recreational purposes both now and in the future (Figure 25). Data were obtained through personal interviews with owners or persons responsible for policies in these properties. Every large forest landowner with holdings of over 5,000 acres within the state was interviewed, except for three who could not be reached. Ownerships were separated into three size classes: 5,000 - 17,000, 17,000 - 36,000 and 36,000 acres and larger. These were further classified as being industrially or non-industrially owned. This study has revealed the following:

a) Large forest landowners (5,000 acres or more) in Louisiana open 77.2 percent of their land to the public. Land listed as being open to the public is usually used by the public for hunting, fishing, or camping; other uses were revealed as minor. Industrial owners, regardless of their ownership size, open a larger proportion of their land to the public than non-industrial owners. In general, as ownership size increases, a larger proportion of it is opened for public use.

b) The smaller, non-industrial owners within the study grouping most frequently do not want the public on their lands under any circumstances. A large part of this may be due to fear of public liability suits, even though Louisiana has a limited liability law to protect landowners.

c) Leasing of forest land for recreational uses is expected to increase, since it is becoming more profitable; it insures some control over the users. Annual hunting leases are most frequently used and are preferred over other types. Although the income received from such leases is not a large part of the landowner's income, it may amount to a substantial sum of money, and this is stimulating further interest in such leases.



Figure 25. Large private ownerships in Louisiana. *Left:* Camping area for public recreational use. *Right:* Boat landing area provided by an industrial owner. Louisiana State University 1177.

d) Collective action on the part of the landowners who lease large tracts to the state for game areas, free of charge, could result in an improved public image and better public relations if proper advertisements were used.

e) If public use becomes incompatible with timber growing, as present owners ex-

pect, some type of controlled use may become necessary, such as the charging of fees. The study implies the possibility that future leasing of land to the state for many types of compatible recreational pursuits may develop as the landowners and the public become aware of the potentials of such uses.

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Southern ILLINOIS University 66-R-3. *A study of the nature of private horseback riding enterprises in Illinois.* Dwight R. McCurdy.

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NEW YORK - State College of Forestry at Syracuse University K. *The use of eye pupillary response as an indicator of aesthetic reactions to forest scenes.* Paul F. Graves, Wiley D. Wenger.

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UTAH State University 739. *Flaming Gorge National Recreation Area as an example of inter-agency cooperation.* Richard A. Ogle.

WASHINGTON State University 1848. *Guidelines for recreation in multiple use land management.* Milton M. Mosher, C. Dudley Mattson.

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WILDLIFE

University of
IDAHO 10

Influence of elk and cattle on reforestation.

Franklin H. Pitkin

This study was initiated to ascertain mortality losses of planted and seeded ponderosa pine and Douglas-fir caused by the trampling of elk and cattle. Different treatments in terms of animal use were established by fences. A twelve-foot-high fence excluded elk and cattle use from one treatment area, and barbed wire fences excluded cattle but not elk use from two other areas. Two control areas with no hindrance to animal movement and one salted area to attract animals were also used. An attempt was made to evaluate mortality differences among these different animal-use areas. Two seasons of field observations have revealed that trampling damage was confined mainly to germinating seedlings from planted seed. The prepared seed bed appeared to provide natural pathways for the elk and cattle. The only mortality losses of planted trees attributed to trampling were on the salted area. The salt attracted elk in such large numbers in the spring that the trees were obliterated.

During the second field season, we attempted to quantify animal use on the area. Plaster of Paris disks were distributed systematically on the treatment areas, and numbers broken were recorded weekly. Electronic counters were placed on two treatment areas and counts were recorded weekly. Observations also revealed that our sample trees were being greatly reduced by mortality caused by the severity of the site and by losses to pocket gophers.

During the second field season, the pocket gopher phase was initiated to investigate the full extent of pocket gopher damage on reforestation losses. To ascertain pocket gopher damage to tree seedlings, four study plots were established. These plots consisted of one rodent enclosure, one pocket gopher enclosure, and two control plots. Tree seedlings were established in each plot by planting and machine seeding. In addition, pocket

gophers were live trapped and held in captivity in order to develop a marking technique by which gopher movements could be determined under snow.

University of
CONNECTICUT 350

Effects of diurnal fluctuations of dissolved oxygen on the growth of juvenile brown trout.

W. R. Whitworth

Diurnal oxygen fluctuations from 11.0 to 3.5 mg per liter restricted the growth of yearling brook trout in 20 to 70 day tests. Oxygen fluctuations to 2.0 mg per liter suppressed development of brook trout sac fry and fry.

University of
CONNECTICUT 340

Fetal sex ratio and productivity of white-tailed deer.

Robert D. McDowell

Management of white-tailed deer, under the "multiple-use" concept, calls for a maximum harvest in keeping with other demands (forestry, farming, watershed management, etc.) upon the land over which these animals range. In order to manage local herds of white-tailed deer efficiently, the agency concerned should know the age-class composition of the breeding females and the productivity rate of each age-class.

Biologists may now rate their individual deer ranges according to a six-point scale based upon the reproductive performance of 8,564 dams examined by local biologists in 20 states in New England, the mid-Atlantic, the southeastern, and the Lakes States region. Fetal data collected by state biologists were reduced to estimate statistically the influence of various environmental factors upon fertility rates of average number of embryos per dam.

Forest and soil were found to exert the greatest influence upon deer fertility; accordingly, the eastern United States was divided into six major fertility regions based upon a forest and soil classification. These fertility regions should prove useful to biologists in making both intrastate and interstate studies.

Infrared detection of simulated animal damage on conifers. Lawrence S. Hamilton, Peter A. Murtha

This research aims to simulate various degrees of animal damage on 4 coniferous species by crown clipping and girdling; to determine if such morphological change can be detected on near infrared film before it is apparent on color film, and to see if the degree of damage inflicted is related to moisture content of the foliage and to optical density, so that estimates of severity of damage may be made by photo measurements (Figure 26).

Density values taken on near infrared film by an optical densitometer a year after simulated animal damage treatment indicates the different levels of damage inflicted on 4 species of conifers. When treatment optical

density values were plotted as deviations from the values of the control trees, the trees which had been subjected to the greatest morphological change showed greatest deviation from the control base line. The possibility of using deviation from a control base as a means of estimating the degree of damage on trees appears good.

In general we found an inverse relationship between the optical density values and percent moisture content of the foliage. In the 1967 growing season when moisture content of foliage was low, the optical density values were high or dark. When moisture content reached a high during the "grand period of growth", the optical density values were lowest or brightest. As the moisture content of the foliage dropped during the latter part of the growing season, the optical density values increased.



Figure 26. Graduate student Peter Murtha photographs conifers treated with simulated animal damage to test its detection by infrared versus color film, Cornell University Agricultural Experiment Station 902.

Since the June sampling, treated trees have shown a darker optical density value than control, except for northern white-cedar. The September sample showed the northern white-cedar control was brighter than the other treatments. (Stem elongation on the cedar had continued until late August.) At the present time, the control trees have the lowest density readings, while the 3/3 girdled have the highest values, followed by the 95 percent crown-clipped trees. The exception is northern white-cedar where the optical density values for the various treatment levels are extremely close, except for the 3/3 girdled trees that died throughout. Severely damaged trees are followed by the 2/3 girdled trees. The exception is white spruce where the 95 percent crown-clipped trees are followed by the 75 percent crown-clipped trees. Other treatment densities are difficult to distinguish from control trees.

State University College of Forestry at
Syracuse University
NEW YORK J

The determination of white-tailed deer population densities compatible with adequate regeneration of managed Adirondack forests.

George Mattfeld, William Tierson

In this investigation of deer density, logging and timber stand improvement are being employed to provide suitable conditions for regeneration of northern hardwoods. Previous studies at the Archer and Anna Huntington Forest have demonstrated that, with provision of light and seed, regeneration of yellow birch and sugar maple can be achieved in the absence of the white-tailed deer. This project is designed to determine the population of deer that will permit adequate silvicultural stocking of these species. Initial stages of the project were completed in 1967. A tally of vegetation was made prior to reducing the herd and creating conditions suitable for growth on two study blocks. The pre-reduction population was estimated with drives; then, by public hunting the herd was reduced by 60 percent.

Vegetative tallies were completed in five study blocks of northern hardwoods. Three of these are in the areas treated with 2-4-5-T and water to remove the understory canopy of beech; and the other two are in areas previously prepared for growth of seedlings. In all cases, regeneration of birch and maple was silviculturally inadequate -- only beech and red spruce could be found over 6 feet in height. A sixth study area was tallied in a deer winter-concentration area to determine the effects of reduced deer pressure in a coniferous type.

In October 1966 the deer population on the 6000-acre study area was estimated from actual count on drives to total 232, or, a density of one deer to twenty acres. For a reduction of the herd of 116 animals after the birth of fawns in the spring of 1967, a controlled public hunt was conducted during the 1966 big game season. In 20 days of hunting 2200 hunters harvested 124 deer, -- equally divided between male and female. The deer proved in poor condition as judged by weight, and antler development, and reproductive tracts indicating low reproductive rate. It appears that in addition to a lack of tree regeneration, the range is not supporting a healthy deer population. Clearly, well distributed, high density of hunters, about half eligible to take deer of either sex, can substantially reduce the deer population. In spring 1967 a search of 30 percent of the study area indicated a crippling and overwinter loss of 15 deer. Thus, the total reduction was close to the scheduled 140 animals.

Winter logging of the overstory was completed on areas where the beech understory had been treated. Maple seed developed well during 1967 and a good seed year is expected. Through July 1967, track counts, observations from vehicles and observations at a lake where deer concentrate to feed on aquatic vegetation, all indicated that the population was approximately one-half its original size.

Effects of selected disturbance treatments in oak-hickory stands of the Southern Appalachians upon production and nutrient content of deer browse.
Burd S. McGinnis, H. S. Mosby

It is recognized that land managers will become more involved in the future with management for non-consumptive wildlife species. A study to evaluate influences of timber removal, wildlife clearings, and forest cover types on bird populations led to the conclusion that cut stands were more important during breeding season and late summer than uncut stands. However, undisturbed stands harbored more birds during winter. In uncut stands, breeding bird density was related to understory development. This

OTHER PROJECTS

CALIFORNIA - Humboldt State College 5. *Investigation of ecology of Prairie Creek Redwoods State Park with reference to the distribution and abundance of Roosevelt elk.*
Gary B. Donart.

University of CONNECTICUT 376. *Habitat analyses of two northeastern cottontails.*
Robert D. McDowell.

University of FLORIDA 1032. *Ecology of wildlife using sites mechanically prepared for pine planting.*
S. L. Beckwith.

University of GEORGIA 11. *Rabbit population response to small food patches in a Piedmont woodland environment.*
James H. Jenkins.

University of GEORGIA 12. *Quail populations in relation to land succession.*
James H. Jenkins.

University of GEORGIA 20. *An evaluation of radioactive contaminants in wild animals of forest lands.*
James H. Jenkins.

University of IDAHO 9. *Computer analyses and simulations of big game population dynamics.*
R. H. Giles.

Southern ILLINOIS University CW-7-67. *Dispersal of white-tailed deer from family units.*
W. D. Klimstra.

suggests that managers might open the crown for increased understory development.

The impact of fire on wildlife foods has been studied. Fire as a forest management tool must influence wildlife habitat. Spring and summer burns in Piedmont, South Carolina were evaluated in a loblolly pine community in relation to wildlife habitat and the production of legumes. Prescribed burns consumed about one-half or less of the surface fuels and did not have a significant effect on major seed producing plants, which serve largely as quail food. The prescribed burns did not cause soil movement. Summer burns produced slightly more browse than did spring burns. Burns conducted for the study were made at a cost of only \$1.38 per acre. Here, this tool of the forester and wildlife biologist proved relatively inexpensive.

LOUISIANA State University 1238. *The influence of the eastern woodrat in hardwood forests.*
L. L. Glasgow.

LOUISIANA State University 1356. *Population studies of penned swamp rabbits in hardwood forests.*
Fant W. Martin.

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Sanford D. Schemnitz.

University of MASSACHUSETTS 5. *Food and shelter requirements of ruffed grouse in relation to energy regimes.*
Robert Bruce Brander.

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Leslie W. Gysel.

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James R. Beer.

NEW MEXICO State University 2. *Use of forest livestock range by mule deer and effect of water on their abundance and distribution.*
John E. Wood.

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University of TENNESSEE 3. *Quail management on forest and associated lands in west Tennessee.* Frederick B. Emerson, Jr.

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RANGE

NEW MEXICO

State University 1

Effects of grazing on wooded rangelands in New Mexico.

Rex D. Pieper

Cattle grazing patterns on pinyon-juniper woodland range shifted during the year. As utilization increased close to water, cattle were forced to graze away from water. On range stocked year long with 19 animal units per section by the end of the grazing season, utilization of blue grama--the main forage species--varied from about 46 percent adjacent to water to less than 15 percent at 1 1/2 miles from water. Such information is useful for determining stocking rates on similar range.

There were considerable shifts in preference based on utilization of forage species. Sideoats grama, sand dropseed, and vine mesquite were preferred from the start of new growth in June until November 15. During the winter, November 15 to March 31, grazing was heaviest on sideoats grama, hairy grama, mat muhly, and three awn grasses. Species preferred during the spring period, March 31 to May 12, were sand dropseed, vine mesquite, mat muhly, and three awns. Cattle diets, calculated as the product of utilization and composition, showed considerable variation. During the growing season and early dormant season, blue grama provided less than half the forage; whereas, in fall and early winter, blue grama made up over 85 percent of the diet. In late winter and spring, secondary species such as mat muhly became important constituents of the diet.

Changes in species composition appear related closely to precipitation; no relationship to grazing patterns has been detected. Herbage production on most sites studied was lower in 1966 than that of the previous two years.

University of
MONTANA 603

The biological and economic aspects of grazing use of forest lands in western Montana.

Melvin S. Morris, Lee E. Eddleman

An extended drought during summer 1967 intensified normal vegetation use patterns. Cattle used forage in shaded areas that remained green; less use was made of mature or dry forage in sunny openings and along stream bottoms due to reduced production and palatability. Moreover, cattle grazed farther from water and through larger areas of timber cover than in normal years.

Study was completed on forage production and utilization in western Montana larch-fir clearcuts. These areas produced more usable herbage than uncut areas; however, burning decreased plant cover and increased undesirable herbage, mainly forbs. At the same time, burning left the clearcut more accessible to livestock movement. When Kentucky bluegrass and white clover communities were close to the clearcuts, livestock use concentrated on these species with little of other species on the clearcut.

University of
WYOMING 879

A study of the forest margins.

Morton May

Little is known about the causes of unstable forest margins and the influence that the invading trees may have on the bordering shrub or grassland communities. Theories on the causes of forest invasion include climatic change, overgrazing, cessation of burning, competition for soil moisture, and plant succession. Forest invasion has special significance from several standpoints. In pure science the effect on the neighboring communities would be of interest. In an applied sense, an understanding of the cause and effects of tree invasion would be prerequisite to developing a management plan.



Figure 27. Forest margins on the move. *Top*: Limber pine invades open grassland slopes, Shoshone National Forest. *Mid*: Engelmann spruce and alpine fir spread into a wet meadow--sedge and willow community, Shoshone National Forest. *Bottom*: Lodgepole pine invasion of bottomland approaches stream on Medicine Bow National Forest. University of Wyoming 879.

In this study of forest instability, the first phase was to correlate the rate of tree invasion with site and vegetation factors. The second phase was to study soil factors of temperature and moisture on forest margins. The third phase was designed to distinguish causes of forest margin instability from their effects on the soil and microclimate.

Sampling of forest margins (see Figure 27) of lodgepole pine, Engelmann spruce, and sub-alpine fir with varied ecological site characteristics, have shown the following:

- a) Age of trees in the margin zone contiguous

- to the mature stand does not differ significantly from tree ages in more distant zones.
- b) Numbers of immature lodgepole trees per unit area are fewer in the zone nearest to the mature forest than at more distance.
- c) Density of Engelmann spruce and sub-alpine fir is greatest in the zone nearest the mature forest.

These results indicate that microclimatic factors, not edaphic, are directly related to the function of tree stability in the forest margins.

OTHER PROJECTS

Northern ARIZONA University 5. *The influence on range production of the removal of trees growing along park boundaries in the ponderosa pine type.*
L. D. Love.

University of IDAHO 1. *Site relationships and productivity of foothill woodland shrub grazing lands in Idaho.*
E. W. Tisdale.

UTAH State University 670. *Effects of range plant foliage removal on soil moisture regime.*
George B. Coltharp.

University of WYOMING 880. *Factors affecting biotic communities of forests and adjacent grazing lands.*
Herbert G. Fisser.

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WATERSHED

UNIVERSITY OF
ARIZONA 631

Effect of forest vegetation on the water and energy budgets of snow in Arizona. David B. Thorud

This key project in our snow hydrology aims at improving water yields from snow-covered watersheds in Arizona by means of land management. This region receives a very high percentage of its surface water from

snow pack areas which are usually heavily forested. The effect of forest cover on the snow regime and also possible methods for manipulating the forest to improve the snow regime deserve concentrated research effort. We are studying vegetation and snow parameters to predict water yield potential under varying stand conditions in ponderosa pine (Figure 28). Vegetation parameters have a functional relationship to the snow accumulation and melt processed under forest cover.



Figure 28. Melt runoff at 7000 feet elevation in ponderosa pine near Flagstaff, Arizona. This water flows to reservoirs on the critical Salt-Verde River system which supplies water to Phoenix and environs. Much surface water in this system is derived from forested, high elevation snow zones. University of Arizona 631.

WASHINGTON
State University 1849

Snow catch in conifer crowns.

Donald R. Satterlund

During the winter of 1966-67, a direct method of continuously measuring the snow load on conifer trees was developed. A water level

recorder was modified to record the motion of a tape attached to a spring type scale. A complete and detailed description of the weighing device is in press.

The sensitivity of our recording apparatus permitted us to measure snow loads on sapling Douglas-fir and western white pine

in considerable detail. We were consequently able to derive a mathematical expression of snow interception storage during snowstorms. During a storm, the snow load increases very slowly at the beginning, but as snow bridges are formed between needles and branches, it builds up rapidly. Thereafter, as flexible branches bend downward under increasing loads, snow begins to fall from the tree. Finally it falls from the tree as rapidly as it falls from the sky and the load on the tree no longer increases.

Despite the great difference in needle structure and arrangement and crown form between Douglas-fir and western white pine, there was little difference in the catch or release of snow from the crowns, either in timing or amount. A provisional snow interception water balance, which accounts for the period January 10 to March 27, 1967, indicated that the probable interception loss on evaporation was less than 5 per cent of snowfall. The moist, warm winter, however, was exceptionally unfavorable for snow interception losses.

Some aspects of the study have achieved little success so far. Despite thousands of measurements of tree morphology, we have not yet been able to describe the characteristics of trees that determine their catch of snow; however, we are continuing the study toward the significant goal of quantifying snow catch in conifer crowns.

UTAH
State University 641

Manipulation of quaking aspen and Gambel oak for increased water yields.
John D. Schultz

This research aims to determine effective means for obtaining prescribed degrees of eradication of quaking aspen and Gambel oak growing on fine-textured and medium-textured soils, and to evaluate relative savings achieved in reduced water loss due to evapotranspiration (Figure 29).

Reductions in the use of soil moisture by transpiring quaking aspen and Gambel oak trees have been achieved on plots in central Utah. Evaporative loss of moisture from the soil profile through trees can be controlled by manipulating vegetation. As much as 4.7 inches of water in the upper six feet of soil was saved in an oak stand which was clear-cut and in which new sprouts were continuously removed. Maximum savings in an aspen stand were 3.3 inches of water in six feet of soil. When the soil moisture is not removed, less water is required during the recharge periods of the year to bring moisture levels to field capacity.

Different degrees of cutting and poisoning by injection in quaking aspen and Gambel oak stands do not appear to affect the sprouting capacity of the trees. Clearcutting results in abundant resprouting. Other levels of cutting do not seem to inhibit resprouting as greatly as has been thought.



Figure 29. Environmental measurements in quaking aspen stand taken by students. *Above:* On the tower, the record of wind and shortwave radiation impinging at canopy level is checked by Jon Engstrom. *Below:* Joseph Coates meters the soil moisture under clear-cut stand to find that this treatment reduced the water loss. Utah State University 641



Impact of land use on water quality.

James R. Meiman

An intense forest fire had little effect on the water quality of a small mountain stream. During the spring and summer of 1967, water quality was sampled above and below a 1,000-foot stretch of stream running through lodgepole pine which had been severely burned during the fall of 1966 (Figure 30). Although the spring snowmelt runoff was expected to flush much of the ash material from the channel, there was little measurable effect of water quality as indicated by sediment, turbidity, pH, total dissolved solids, or coliform, fecal coliform, and fecal streptococcus

bacteria. A storm on August 8, 1967, resulted in a stream rise 0.18-foot in 3 1/2 hours and caused a fourfold increase in the coliform bacteria count. Other water quality indicators remained unchanged. The increase in coliform organisms occurred although the peak storm runoff was well below the peak of the snowmelt runoff of June 7, when no detectable increase occurred in any of the water quality measurements.

In addition to the study of the burn impact on water quality under natural flow regimes, the effects of ash materials injected artificially into the stream at various levels are being studied. Work on quantifying the variation associated with bacteria sampling of mountain streams approaches completion.



Figure 30. Water quality sampling stations above and below the burned-over lodgepole pine forest. Lower station includes 18-inch Parshall flume used to measure runoff.

Colorado State University 312.



OTHER PROJECTS

CALIFORNIA - Humboldt State College 3. *Soil-water-vegetation relations in the Douglas-fir zone of the Northern California Coast Range Preserve.*
Douglas Jager.

CALIFORNIA - Humboldt State College 3. *A snow hydrology study to evaluate the winter recreation potential of the Horse Mountain ski area in Humboldt County.*
Douglas J. Jager.

University of MASSACHUSETTS 2. *Evapotranspiration, run-off, storage, and drainage characteristics of forest soils.*
Donald L. Mader.

PENNSYLVANIA State University 1495. *Forest cover and timber harvesting methods on streamflow in central Pennsylvania.*
W. E. Sopper, R. E. Melton.

University of RHODE ISLAND 954. *Evapotranspiration losses as related to site and vegetation differences.*
J. H. Brown.

UTAH State University 733. *Data reduction methods for streamflow from small wildland watersheds.*
G. E. Hart.

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Lull, H. W. and W. E. Sopper.
1967 *Prediction of average annual and seasonal streamflow of physiographic units in the Northeast.* Int. Symp. Forest Hydrol. 507-522. Pergamon Press, N.Y.

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Sopper, W. E. and H. W. Lull.
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MULTIPLE-USE

University of
VERMONT 6

Economics of multiple use of forested land.

Frederic O. Sargent

The scenery classification system was used to demonstrate an analysis of lake basin scenery, selection of hills for scenic spurs, analysis of mountain passes, and town planning. The demand for forest land for non-forestry uses was investigated through interviews with special interests groups. A model for reorganization of multiple uses of forested land was developed on the basis of this information. The purpose of the model was to maximize all the uses as far as possible.

University of
RHODE ISLAND 125

Development of Rhode Island forested lands.

Charles P. Gratto

Severe pressures on the forest resource will result, should the projected increase and distribution of the population occur. Without a state wide land use plan, implemented with a variety of institutional devices, there will be a serious deterioration of the Rhode Island forest resource. The amount of forest land and open space per capita will decline greatly unless specific provisions are made to preserve the resource. Areas under the greatest pressure from land use change have been identified, and alternative ways to relieve this pressure studied. Of the alternatives, deferred taxation of forest and open space uses shows the greatest promise of being of immediate practical use. To relate quality of environment to the presence of forest land, a social index made up of income, occupation, and education was used as a proxy measure of environmental quality. This social index, in the area of the state containing the newer cities and the rural and suburban areas, was related to quantity of forest land and quantity of urban uses. This indicates that forest land is linked in some way with the higher levels of living found in the more rapidly growing part of the state.

Purdue University
INDIANA 1354

Optimizing recreation, timber or alternative enterprises.

John C. Callahan

Rural and urban areas of southwestern Indiana are characterized by lagging economic growth and development, under-utilized natural and human resources, net outward migration, and agricultural land abandonment. The land surface of the region has been subjected to extensive surface-mining-for-coal activities which have disrupted and overturned about 100,000 acres of land. The region was singled out on the basis of a previous investigation in southern Indiana which emphasized the economic disadvantages, and it was termed a "recreation desert."

In the light of recreation demand, projections of increasing leisure time, and a more mobile population traveling over improved highways, investigations were made to inventory the recreation potential comprehensively. Special attention was given to surface-mined areas. Findings confirmed conclusions of other studies with respect to the typical outdoor recreationist visiting the 18 public and 44 private facilities in the 18 county region. Family groups of 4-5 were the common recreation-seeking unit with the husband-father characteristically 35-40 years of age, high school educated, and a craftsman, service worker, or manufacturing employee. He had 25-72 hours of discretionary free time available for recreation each week in addition to a two-week paid vacation. Family income averaged about \$7,500. A few lived in urban Indiana environments and had traveled 45-65 miles to reach their recreation "spot." Extremes of poverty or wealth were lacking. Regional planning should provide for recreation areas suitable for use by these groups.

Recreationists interviewed were primarily water oriented. This may provide the means for more fully utilizing and capitalizing on the 10,000 acres of water resources developed as a by-product of the surface mining process (Figure 31). Some of these water areas are already immensely popular whether managed by the public or by private entrepreneurs.



Figure 31. Private recreation cottage on a pond created by surface-mining. Purdue University 1354.

OTHER PROJECTS

University of ARKANSAS 610. *A comparison of land use alternatives on forest lands of the Ozark Upland Region of north Arkansas.*
F. M. Meade, A. M. Davis.

University of MONTANA 2001. *Economic analysis in evaluation of combinations of resource uses under a multiple-use objective.* William K. Gibson.

University of NEVADA 672. *Recreational uses and factors influencing their quality and quantity in isolated forest and rangelands of northwestern Nevada.*
C. M. Skau, P. T. Tueller.

NEW JERSEY - Rutgers University 256. *Evaluation of the multiple uses of New Jersey's public forest land resources.*
Richard F. West.

PENNSYLVANIA State University 1494. *Wildland recreational management.*
J. L. George,
J. S. Lindzey, R. A. Bartoo, W. W. Ward.

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Gratto, C. P.
1967 *Plow now, pay later-open space tax deferrals could help keep Rhode Island beautiful.* R. I. Agr.

Gratto, C. P.
1967 *Recreation is a risky business.* R. I. Agr.

Sargent, F. O.
1967 *Scenery classification.* Vt. Agr. Exp. Sta. Vt. Resources Res. Center Rept. 18, 28 pp.



Forest Economics and Marketing

In the area of market analysis as well as economics, most of the projects are computer oriented. Additional projects involving economic methods or objectives are to be found in other sections appropriate to their subject matter emphasis. The economic and marketing problems relate to timber supply, harvesting methods, transportation, processing, and markets. Sources of data include questionnaires and personal interviews. Often it has been necessary to make resource and processing inventories.

ECONOMICS & MARKETING

Southern

ILLINOIS University 65-R-13

The taxation of forest and associated lands in Illinois in view of their changing uses and possible organization.

Ronald I. Beazley

Further progress in appraisal methods for forests and associated lands in southern Illinois was brought out in a recent master's thesis. To provide equitable taxation, the following recommendations were given: adequate training, certification for office, and competent supervision should be provided for the tax assessor to fit him for his responsibilities. The Illinois State Department of Revenue should assist the local assessors by devising a uniform State tabulating and recording system of property sales. In addition, adjusted tax and value mapping should be provided. Finally, there are numerous changes needed in property tax administration, supervision, control, and enforcement of current statutes.

NORTH CAROLINA

State University 4003

Analysis of the foundations of American forest policy.

Joe O. Lammi

The objective of this research is to identify and analyze forest policy developments of the U.S. wood products industry and formulate judgments as to their probable impact on forest management. Preliminary indications point out the most pressing problem effecting policy; the need for reducing pro-

duction costs in the face of unfavorable profit prospects in many segments of the industry. This is leading to vigorous experimentation with cost-reducing measures such as new equipment and to output-increasing measures such as forest fertilization and tree improvement. The competition of substitute products, deficiencies in intra-industry cooperation (e.g. in product standardization, legislative matters), market difficulties in foreign trade, and competition for raw materials are other important problems in policy.

Statistics indicate that sawnwood output has increased faster than anticipated by the U.S. Timber Trends, being about 4 years ahead of anticipated volumes. Increases in sawnwood and pulpwood consumption show similar trends. The acreage of commercial forest land, volume of growing stock, and net annual growth are likely to show some declines as already evident in 1966 figures for North Carolina. Some unfavorable "straws-in-the-wind" are the apparently irrational location and overcapacity of pulpmill installations in some Southern States (e.g. Alabama), losses of high quality forest sites and growing stock to agriculture (e.g. soya beans), and competitive rather than complementary industry diversification (e.g. pulp industry and plywood industry). It is evident, also, that the increasingly critical competition for labor, the change in raw material needs toward locally-scarce and difficult-to-grow hardwoods, and the continuing paucity of significant innovations in wood harvesting and processing are unfavorable developments to which forest managers must respond through policy adjustments.

VIRGINIA

Polytechnic Institute 11

Increasing the efficiency of forest management decision-making. Emmett F. Thompson.

A major responsibility of an industrial woodlands department is to furnish the wood processing plant with the required raw material at a minimum cost over time. When considering wood procurement over time, a large number of procurement alternatives exist. The problem is one of allocating the procurement alternatives within a time period to achieve minimum procurement cost over the entire period.

Linear programming is recognized as an efficient allocation technique; however, it assumes constant costs and prices. In a long term problem, this assumption seems unrealistic. To overcome this difficulty, this project employed a slight modification of linear programming, termed linear programming over time, which is a system whereby expectations about such things as costs which increase over time can be included in the problem formulation.

To illustrate the usefulness of linear programming over time, operational data supplied by a cooperating firm were used to formulate a long term wood procurement problem. After the problem was formulated and solved, the solution was compared with the firm's current procurement practice. In general, the linear programming over time solution substantiated the firm's current procurement practices.

University of
ALASKA 7500

Marketing Alaska's timber products, Phase II: marketing chips for pulpwood from the Haines area of Alaska. Michael R. C. Massie

This project, now nearing completion, will indicate the potential for manufacturing and marketing pulpwood chips from the Haines area of Alaska. The study concerns current utilization and milling which is focused on the manufacture of spruce and hemlock cants

for the Japanese market. Plot samples in logged sale areas and input-output analyses at mill sites indicate sufficient volumes in small marginal logs and in mill slabs to provide the input for large chipping facilities. The manufacture of pulp chips would appear to serve as a complement to available timber residues and utilization facilities. Market alternatives are available and within reach.

As increased economic benefits should be realized with more efficient utilization, the study was expanded with the cooperation of the U.S. Forest Service to ascertain possible changes in the local economy. Emphasis here is being placed on the role of the forest products sector in relation to the total economy of the area. Model formulation is being attempted in which different variables (i.e. employment, gross income) can be evaluated so that a model might be used in other Alaskan locations without individual studies.

TEXAS

A&M University 1524

Requirements and distribution of wood products manufactured and used in Texas. H. B. Sorenson

The primary agents involved in the production and marketing of pulpwood in Texas include roundwood producers, chip producers, roundwood dealers or contractors, and primary pulp manufacturers. All firms purchasing pulpwood produced in Texas follow the same basic pattern. Roundwood is purchased through independent dealers, while chips are purchased directly from producers. The major points of delivery for roundwood are company mill yards, company wood yards, and rail sidings. Chips are purchased f.o.b. shipping point and f.o.b. pulp mills. Approximately 70 Texas dealers purchased roundwood in the state during 1965; some of them sold wood to pulp mills outside the state.

The production of chips from wood residues that were formerly burned had significant impact on the lumber and pulp and paper industry in Texas, (Figures 32, 33). Chip production has become an important source

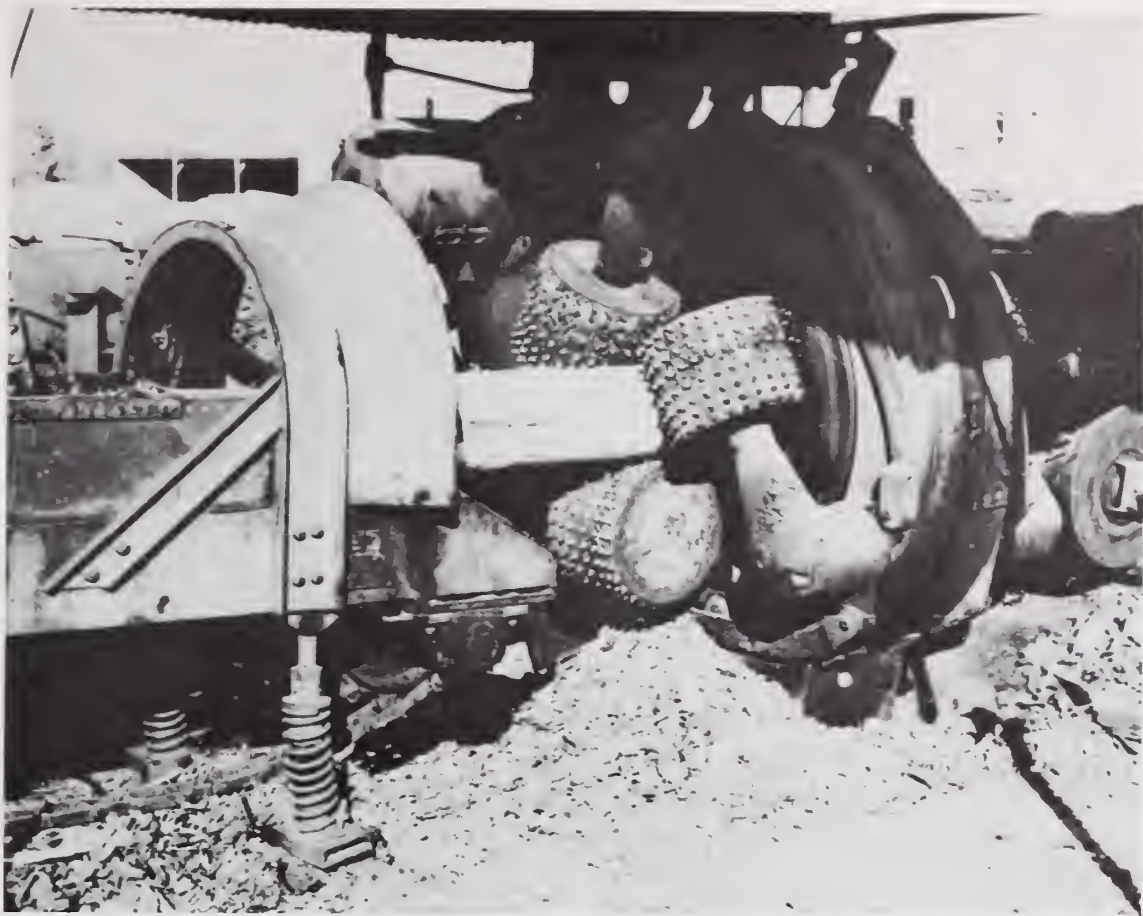


Figure 32. Debarkers used by Texas chip producers. *Above:* Cambio debarker, the main type. *Below:* Morbark is another type of debarker in use. Texas A and M 1524.

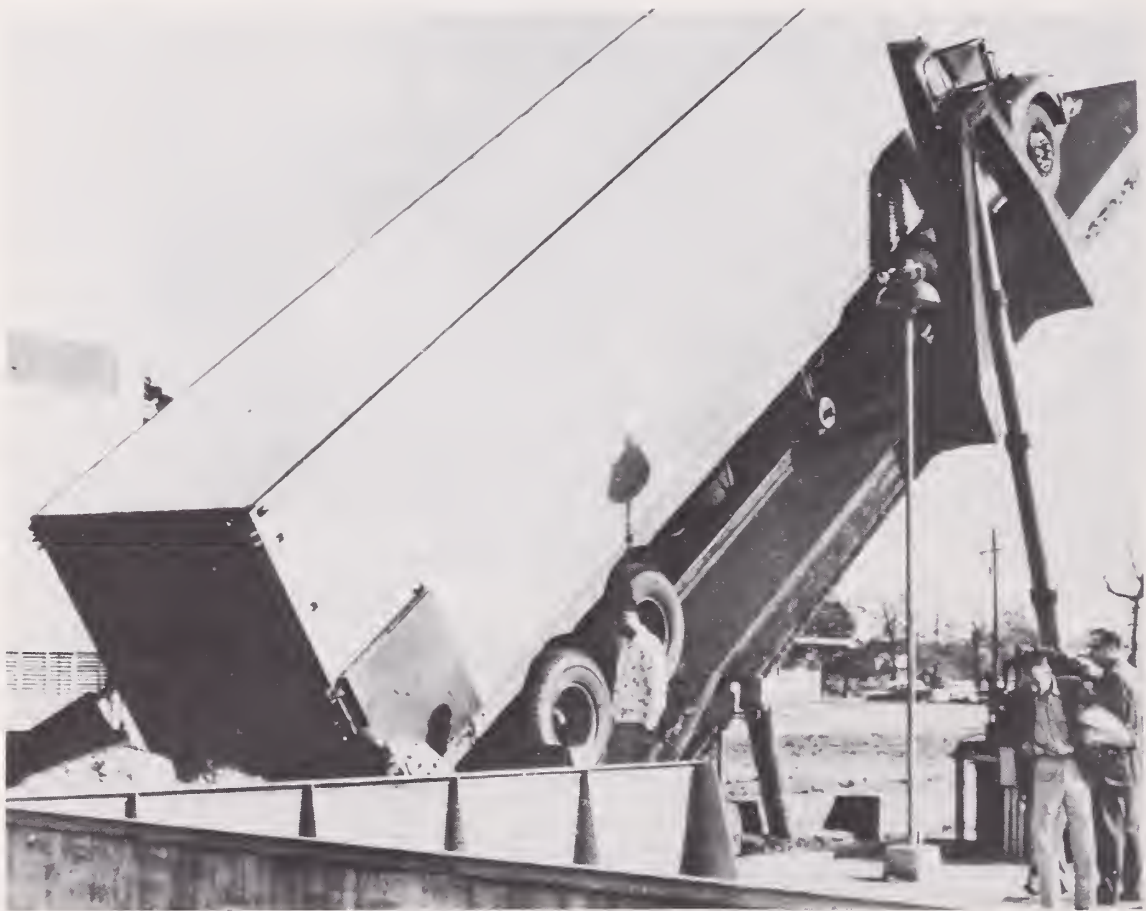


Figure 33. Chips produced from wood residue for pulp manufacture. *Below:* Unloading by truck-lift into storage pits. *Above:* Stock-piled in open until use. Texas A and M 1524.

of revenue to the lumber industry. The total sales value of Texas chips was over \$6.5 million. The average initial investment required to produce chips by 37 Texas firms was \$112,089 with ranges from less than \$50,000 to more than \$300,000.

University of
VERMONT 5

Roundwood use and requirements on rural ownerships in Vermont. Roy A. Whitmore, Jr.

This project was terminated during 1967 with a report of findings. In Vermont, two-thirds of the nearly 1 million cubic feet of posts and poles purchased and cut on privately owned land during 1963 was white cedar. Treated posts and poles processed from under-utilized species appear to be logical replacements for the commonly used but rapidly disappearing white cedar. However, decreasing numbers of farms and changing agricultural technology indicated a downward trend in the future requirements for these products. Although this is occurring,

OTHER PROJECTS

University of CALIFORNIA 2350. *Methods of estimating long-range timber supply.* Henry J. Vaux.

University of CALIFORNIA 2352. *Forecasts of market characteristics for redwood lumber.* W. L. M. McKillop.

University of CALIFORNIA 2353. *Inventory control in lumber manufacturing.* W. L. M. McKillop.

University of CALIFORNIA 2505. *The role of oligopsony and monopoly in markets for publicly owned timber in California.* Henry J. Vaux.

University of IDAHO 6. *Potential markets for cut-up lumber stock from the northern Rocky Mountain region.* E. L. Williams.

University of ILLINOIS 310. *The major technical, production, and marketing problems of the secondary wood-using industries of Illinois.* I. Irving Holland.

present markets and those for several years in the future indicate a demand which will continue to deplete an already meagre white cedar resource.

University of
VERMONT 3

Industrial markets for shipping lumber in Vermont. Roy A. Whitmore, Jr.

This project was completed in 1967 and it was found that the largest consumers of shipping lumber in Vermont are stone and cement manufacturers followed by machinery, tools, and metal product manufacturers. Softwoods, half of which was native spruce, comprised about 85 percent of that utilized. This was 1/8 of the total softwood produced in Vermont. Intermediaries play a minor role in lumber marketing since most users rely upon direct purchasing from sawmill producers. Shipping lumber will continue to utilize a portion of lower grade softwood lumber in Vermont.

Southern ILLINOIS University 67-R-1. *An approach to the economic allocation and use of resources for forestry and allied purposes.* Ronald I. Beazley.

KANSAS State University 670. *Investigations pertaining to the marketing of forest products in Kansas.* Paul L. Roth.

LOUISIANA State University 1233. *Lumber distribution patterns in Louisiana.* William C. Hopkins, deceased.

University of MARYLAND A-26-by. *An economic analysis of the forest marketing structure in Maryland.* Harold D. Smith.

MICHIGAN State University 980. *Hardwood utilization and marketing.* Aubrey E. Wylie.

University of MINNESOTA 19-57. *Restraints to aspen lumber supplies from Minnesota sawmills.* Robert D. Thompson.

MISSISSIPPI State University 1124. *Availability, consumption, retail marketing practices, and species preferences for softwood lumber in Mississippi.* Fred W. Taylor, Warren S. Thompson.

- University of MISSOURI 543. *Financial aspects of silvicultural practices in immature timber stands.*
Richard C. Smith.
- University of MISSOURI 617. *Public assistance programs.*
J. Milford Nichols, Richard C. Smith.
- University of MONTANA 202. *Marketing Montana lumber.*
Arnold W. Bolle.
- University of NEW HAMPSHIRE 2. *An empirical application of mathematical programming models to planning over time in the large forest firm.*
Robert H. Donnelly.
- NEW YORK - Cornell University 904. *Analysis and evaluation of New York State fish and wildlife management act.*
L. S. Hamilton, J. W. Kelley.
- PENNSYLVANIA State University 1625. *Increasing the operating efficiency in forest products industries.*
P. C. Kersavage, W. K. Murphey.
- VIRGINIA Polytechnic Institute 61. *An econometric study of resource use in the southeastern logging industry.*
Douglas P. Richards.
- University of WASHINGTON 19. *Structural change in the forest products industries of the Pacific Northwest.*
Thomas R. Waggener.
- University of WISCONSIN 1351. *Development of forest resource based income and employment opportunities in Menominee County, Wisconsin.*
Duncan A. Harkin.
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W. R. Bentley.

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Forest Utilization

The three sections included here, logging, wood science, and products, are really an account of what takes place before a tree can be utilized. We must get the tree away from its environment, we must physically and chemically describe all its component materials, and finally, we must fabricate it into something that can be described as useful. Various aspects of this transition are dealt with in the research projects included in the following sections. Each project contributes toward the dynamic sequence of making something useful of wood.

LOGGING

SOUTH CAROLINA
Clemson University 707

Logging Costs.

W. A. Shain

Research in logging cost studies has been carried out through two separate graduate research projects conducted in different parts of South Carolina. The first project was designed to evaluate several skidding machines and, on the basis of the evaluation, to select one most suitable for logging in the Coastal Plain region. Results showed that it was infeasible to select a particular machine because timber production was influenced largely by the quality of supervision and the efficiency of the logging crews. Continuous variables such as average diameter of the trees of the stand and their basal area, as well as more discrete variables such as supervision, underbrush density, and stand bogdown, had a highly significant effect on production efficiency.

The second project is centered on the delays encountered in normal cutting operations and on the factors having the greatest influence on logging production. Preliminary results indicate that skidding distance has the greatest effect on production. If this distance ranges from 950 to 1,000 feet, timber production reaches the breakeven point regardless of stand factors or logging conditions acting separately or jointly. With distances beyond 1,000 feet, production efficiency decreases accordingly.

University of
WASHINGTON 7.

Evaluation of timber harvesting methods presently being employed in Pacific Northwest second growth timber stands.

George Stenzel

Manufacturers and operators of timber harvesting equipment in Europe and in the United States were surveyed for information on systems that could be adapted to thinning operations in the Pacific Northwest where yarding is the greatest problem on ground too steep for tractor skidding. Field examinations concentrated on operational procedures of thinning, and collection of time and cost data for certain skyline systems being used to harvest thinnings. A significant portion of this report came from a thesis that dealt with the economics of thinning young second-growth Douglas-fir stands on steep ground and with an evaluation of logging systems that were applied to thinning such stands.

On rough and steep ground, a pre-commercial thinning was suggested 5-10 years before the first commercial cut, to be followed by removal of 35 percent of the volume at the first commercial cut. Thinning could be at 8-10 year intervals and fertilizer could be applied after each of the last two thinnings. Knowledge of high-value timber specifications and careful planning and design of a thinning lay-out were essential for an economically successful operation. After comparison with others, skyline systems appeared to offer the best economical solution. Studies of skyline operations in thinnings

indicated that the amount of damage to residual stands amounted to far less than the amount of increment growth.

Timber harvesting equipment consisted of:

a) The Berger Slack-Pulling Carriage b) The Bullet (RCC-1p) c) The Wheel, and d) The Wyssen automatic 5-ton carriage.

Hourly operating costs were calculated for these four on a high-lead thinning operation. Prediction equations, expressing time of the various phases of the yarding cycle as a function of distance, were developed for the Berger Carriage, the Bullet, and the Wheel. Average cycle times were calculated for the Wyssen system, based on time study data.

The study indicated that the Berger had a maximum economical yarding distance of

800 feet. A comparison of the Bullet and the Berger Carriage revealed greater profit in the Berger Carriage operation for all distances below 800 feet. The Wheel was found to be an efficient skyline carriage for a clear-cut operation. Under certain logging conditions, the Wheel was suitable for a thinning operation. A study of long span and short span systems indicated lower direct logging costs for the short span systems even where extra road building costs were considered.

Other logging systems investigated were the Isachsen two-drum winch, the Vinje Radio-operated skyline system, the Koller Cable Crane, the Telematic J 3, the Radio operated Cable Crane, and the URUS 66 skyline system. Of these the URUS 66 was considered to have the functional requirements closest to what might be described as ideal.

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none

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WOOD SCIENCE

MISSISSIPPI

State University 1126

Anatomical, chemical and physical properties of Mississippi delta hardwood species. Fred W. Taylor

A study of the anatomical and chemical properties of black willow has been completed and a manuscript prepared. Wood property variations within the trees of black willow were as follows: a) Density increased slightly with increasing height in the tree. For the 5- to 25-foot heights, density increased from ring 2 to ring 8; beyond this point it levelled off. b) Cell length, cell wall thickness, and cell diameter increased with distance from the pith at all heights. Length within trees varied from 0.75 to 1.28 millimeters and wall thicknesses varied from 2.42 to 3.90 microns. c) Vessel volume generally increased with distance from the pith and with increasing height while ray volumes were fairly uniform. d) Holocellulose yields increased with distance from the pith; patterns of vertical variation were not evident. Interrelationships of wood anatomical variations for black willow revealed: increased volume of vessels in slower growth increments, reduced vessel volume with decreased specific gravity, and association of thicker cell walls with longer cell lengths.

An additional research effort will describe the geographic variation of selected wood properties over a major portion of the economic range of black willow; sampling along the lower reaches of the Mississippi River deals with density and cell length.

Investigations of the anatomical and chemical properties of willow oak, the second species selected for study, are in progress. Trees are intensively sampled to establish vertical and radial patterns of anatomical variations, and to relate these to variations in physical properties. Density and cell dimension studies are underway on willow oak.

University of
GEORGIA 1

Effect of thinning on variation in diameter growth and specific gravity with position in stem for loblolly pine and slash pine. L. W. R. Jackson

The effect of moderately low thinning on basal growth and specific gravity was determined for 20-year-old loblolly pine and slash pine. Samples were collected from superior dominant trees 10 years after thinning at 4-foot height intervals from 2 to 30 feet. For all plantings, growth accelerated the first year after thinning, peaked at 6 years, and rapidly decreased the final 4 years. Specific gravity at all heights gradually decreased prior to thinning; after this, specific gravity increased for 8 years and then again decreased. Specific gravity of both species decreased with stem height. In an unthinned loblolly pine stand, basal area growth decreased gradually during the entire time over which growth was measured.

OKLAHOMA

State University 1246

Variation in wood properties of shortleaf pine in eastern Oklahoma. Clayton E. Posey

Increment cores were collected from ten trees on each of 50 plots. Because extractive content accounted for a large portion of the variation in unextracted specific gravity, interpretation of environmental influences on specific gravity was not always identical for extracted and unextracted specific gravity. Unextracted specific gravity figures will result in considerable overestimate of cellulose yield. Site index and age of tree can be useful for the prediction of extractive content. The average unextracted specific gravity for wood produced during the first thirty years growth ranged from .47 to .60. Extracted specific gravity for wood from the same sources ranged from .42 to .51. The average values for unextracted specific gravity did not maintain their relative rank after extraction.

Samples from some geographic sources showed rapid increase in percent summerwood for the first ten years after which it leveled off. Material from other sources did not level off at age ten but percent summerwood continued to increase with age. Areas with low summer rainfall or extremely droughty soils tend to produce wood with a low percentage of summerwood.

The length of whole tracheids was determined for summerwood samples from the 11th, 15th, and 20th annual rings. Average tracheid length for material grouped by sources ranged from 2.88 mm to 3.65 mm. These data indicate that because of wide variation in rainfall, elevation, temperature, and soils, there is more phenotypic variation in shortleaf pine in Oklahoma than in any area of comparable size in the total range of the species.

University of
MASSACHUSETTS 4

Technological properties of wood from forest tree species in the northeast. William W. Rice

Initial tests on wood from 40-year old plantation-grown red pine indicated that density and strength properties were abnormally low for this species. However, the material tested was dominated by juvenile wood. Therefore a single typical tree was examined to determine density and impact strength variation from pith to bark at each internode from base to crown. The test results confirmed that, as apparent maturity is reached and growth rate slows down, density and strength properties increase. Specific gravity increased from 0.36 near the pith to 0.49 near the bark. Impact strength values varied from 0.53 foot-pounds near the pith to 2.35 foot-pounds in the outer-most growth rings. The data suggest that mature wood formed in plantation-grown trees may equal natural forest-grown trees in strength properties. Working plans have been developed for continuing the study along three phases of investigation, drying characteristics, dimensional properties, and machining studies.

University of
MONTANA 401

Variability of western larch wood: Its relation to growth, quality and use potential. John P. Krier

Western larch wood exhibits considerable variation in its physical, chemical, and mechanical properties. It is generally recognized that the specific gravity (density) of wood is a good indicator of strength and elastic properties. From the various tests performed on larch, reliable correlations have been established between specific gravity and strength, as was expected. The apparent specific gravity of western larch was influenced by the presence of variable quantities of water-soluble extractives, such as arabino galactan. These extractives do not increase most strength properties, but add only to the specific gravity. When strength values were plotted against the extracted (true) specific gravity, a closer correlation was obtained. Although the correlation has not been well established, there seems to be an indication that specific gravity and strength was related to annual ring width. Preliminary indications show that the extractives may influence the rate of drying and the equilibrium moisture content. Research is continuing on the development of techniques and apparatus for the removal of extractives from solid wood samples of relatively large size. Other phases of the study, in which anatomical and physical characteristics are related to specific gravity differences and to "brashness" of breaks in static bending, are continuing.

Northern
ARIZONA University 2

Wood quality in second-growth ponderosa pine. Glenn Voorhies

Regression analysis was employed to evaluate the relationship between specific gravity and selected environmental conditions and internal characteristics in 447 ponderosa pine trees. Of all the selected environmental conditions, only elevation was useful in explaining the variation in specific gravity within this

group of trees. Only variables closely related to the tree itself showed significant coefficients of determination. Specific gravity prior to extraction explained the variability associated with the extractives. Percent of latewood accounted for 20 percent of the total variation while the remaining variables in a multiple regression account for only 0.081 percent. A considerable amount of variation remains unexplained which suggests that more sensitive variables such as tracheid wall thickness, precipitation, and soil moisture might be included in the analysis.

Another phase of this study covers the detailed examination of five second-growth ponderosa pine trees in order to analyze relationships between specific gravity and such variables as extractive content, age, growth rate, and percent of latewood. Preliminary examination of the data indicates: a) a high correlation between extracted and unextracted specific gravity, b) that growth rate does not materially influence specific gravity, c) that the extractive content may be greater in earlywood than in latewood, and d) a very limited relationship between percent of latewood and specific gravity. Additional data will be needed to definitely establish these relationships. A second phase of the detailed study involves determination of fiber length in young-growth ponderosa pine. Preliminary analysis indicates a high correlation between fiber length and age or tree radius, a maximum individual fiber length of 5.9 mm, and fiber length maturation age of approximately 50 years.

OREGON

State University 786

Structural variation in Douglas-fir bark.

R. L. Krahmer

Ideally, variations in bark structure would explain variations in the external appearance

of bark, and these variations could be classified in a meaningful way. However, bark structure in Douglas-fir, as determined by tree growth, is largely masked on the outer surface by cortical tissue in young trees and by environmental influences in older trees.

Fungal activity in Douglas-fir bark not only modifies the external appearance of the bark, but also seems to be quite selective as to the nature of attack. In mature trees some bark appears flaky, while in others the bark is furrowed. A brown rot fungus appears to be associated with flaky bark and is most prevalent in trees on wet sites or on damp sides of individual trees.

Radial cracks appear in cross sections of bark and are bordered on the innermost side by distorted and finely-divided cork layers. This distortion is the result of abnormal cell formation caused by fungal activity in the "fungal furrows" at the interface of inner and outer bark. This activity causes longitudinal planes of weakness along which bark may crack as the tree grows, and some of the "fungal furrows" are combined to become the large fissures observed on the outer surface of the bark.

Specific fungal attack has been observed in the sclereids (bast fibers) and surrounding parenchyma. One organism attacks sclereids and "bleaches" them white by removal of lignin from the cell walls. Also, in some bark, fungi appear to penetrate both sclereids and parenchyma in the outer bark and metabolize the extractive materials within the cell cavities.

Many other organisms also reside in the bark, such as lichens, mosses, and insects, and serve to influence the constantly changing external configuration of Douglas-fir bark.

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- University of CALIFORNIA 2495. *The chemistry and utilization of bark.*
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Benjamin A. Jayne.
- OREGON State University 647. *Gamma radiation induced reactions of flavonoid compounds from bark.*
R. J. Molyneux.
- OREGON State University 763. *Anatomical and chemical characteristics of permeable and refractory western hemlock.*
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R. T. Lin.
- PENNSYLVANIA State University 1489. *Rheology of wood cellulose in situ.*
W. K. Murphey.
- University of TENNESSEE 9. *Hardwood characteristics.*
H. A. Core.

TEXAS A & M University 1527. *Silvical requirements for optimum development of loblolly pine in east Texas.*
Robert R. Rhodes.

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PRODUCTS

Purdue University
INDIANA 1353

Analytical design of wood trussed rafters.

Stanley K. Suddarth

The main purposes of this project are to find new and better means for accurate analysis of wood trussed rafters and to adapt these means to computer treatment to further enhance the economic and engineering position of this important wood component. The most significant advance this year lies in the analytical area. A detailed study of the applicability of matrix methods to the analysis of wood structures provided the foundation for development of an analytic procedure of sufficient power and scope to extend even beyond the wood truss to related structures in three dimensional space. In addition, the matrix method is ideally adapted to computer programming and exhibits strong possibilities toward reduction of costs in preparing the usual truss analysis problem for computer treatment.

All structural analysis is performed through simulation of the real structure by an analog of geometry, material properties and forces, and forces amenable to mathematical analysis. An all-important consideration in devising an analog to be associated with a computer analysis is that it should be applicable to a wide variety of real situations. The outlook at the present time is that the analog created here is so general and flexible that a single program can accommodate several thousand times the variety of design situations heretofore soluble by any known individual program.

A program for plane structures has been developed in an elementary form and its early trials indicate that a finished general program can be generated within the year. A program for treating three dimensional structures is planned as a subsequent development. The latter will open possibilities for engineering design of wood structures heretofore impossible because of the overwhelming amount of simultaneous solution

required in even a relatively simple situation.

Work planned for next year will concentrate on refinement of the matrix computer method to produce a quick, low-cost means of accurately analyzing any pattern of wood trussed rafter supported in any desired way and subjected to any practical combination of uniform and concentrated loads. The joint types covered in this phase will be either relatively rigid or relatively flexible and non time-dependent.

University of
KENTUCKY 1015

Use of Appalachian lumber in fabricating structural timbers and frames.

J. N. Walker

The purpose of this research is to determine the characteristics of wood finger joints and to evaluate their possible use in structural frames. Initial work consisted of mounting strain gages on the specimens and recording their readings during load tests. Analysis of strain was not completely satisfactory, although some insight into the stress pattern was gained. In particular, the expected high stress concentration at the inner corner was confirmed. The strain values changed so rapidly in this region that it was impossible to accurately map them with strain gages. Photoelastic coatings and polarized light were employed to obtain a more accurate analysis of strain in such joints. When the applied load was such that the inner corner was in compression, the stress concentration led to a crushing, or buckling failure at the inner corner prior to the tension failure that eventually took place at the outer corner. The damaging stress concentration at the inner corner was successfully eliminated by a flattened undercut fillet. The stress concentration and subsequent failure occurred in the clear wood away from the finger joint area. Additional work is needed to define the optimum design of such fillets.

The study on the gluing of high moisture content lumber has been completed and the data have been statistically analyzed. The study

showed that wood having high moisture content can be glued with casein and resorcinol adhesives. Though there is some reduction in bonding performance, the strengths obtained for many samples exceeded the normal allowable design strengths. Resorcinol adhesive was superior in performance to casein for all treatments. There was little difference in the strength of the joints whether the surface of the wood was rough or planed. The study showed that reasonably strong bonds can be obtained with wood having an average moisture content above the fiber saturation point. Since most dimensional changes occur as moisture contents are reduced below the fiber saturation point, if the results are applicable to complete structural systems, fabrication could be performed before such dimensional changes occurred. This would eliminate the need for the surfacing of the wood and the subsequent loss of material. The applicability of the results of this study to complete structural systems involving larger numbers and sizes of members need to be determined.

PENNSYLVANIA
State University 1492

Examination of variables involved in kerfless cutting with a knife. Wayne K. Murphey

If a raw material is in a form that can be readily dried, surfaced, glued, sized, and wrapped in minutes after being cut, then certain economic technological advances can be utilized. Sliced wood has the attributes to fit into such a system. It is thinner than lumber, can be produced with a minimum waste, and can be controlled within specified limits. If a system is generated that utilizes cants or even defect-free material within a cant as raw material for a slicer, then possible upgrading of low quality lumber may be accomplished.

With these suppositions in mind, two slicing machines were constructed to cut 0.2 inch laminae. Fifteen-inch yellow-poplar flitches were prepared for slicing by hot soaking at 40°C for at least four hours. Slices and sawn controls were obtained, dried, and glued

into beams. The results of the modulus of elasticity and elastic resilience (work to proportional limit) determinations indicate that the slicewood was more flexible and had a higher elastic resilience. A significant difference at the 1 percent level existed between the slicewood and the sawn material.

The static bending tests indicated differences due to slicing. When comparable assemblies were tested, the sawn material had superior strength. The knife checks in parallel sliced material were perpendicular to the span and thus effected the strength in bending. Comparison between individual laminae and horizontal laminated beams showed that these were not different. Any reenforcement by the glue line was not sufficient to overcome the failure induced by the knife check.

University of
MINNESOTA 19-56

Prefreezing to speed drying of hardwoods.

Robert W. Erickson

Research has been concentrated on the application of a prefreezing process as an aid to the drying of redwood and other difficult-to-dry species. In addition, some basic studies were attempted to obtain better understanding of why prefreezing of refractory species improves their drying, both with respect to rate of drying and to reduction in drying defects.

A field study to test the prefreezing process on redwood lumber on a "pilot plant" scale was made at Scotia, California. Results were very encouraging. Collapse was practically eliminated by prefreezing, and shrinkage was reduced by almost one-half. Although collapse occurred in 113 of 176 control boards, only 2 of the 176 face-matched prefrozen boards showed collapse even with a greatly accelerated kiln schedule. Gross-sections of representative prefrozen and control redwood boards are shown in Figure 34. Drying time for this prefrozen lumber was less than 9 days as compared to the approximate 28 days required with contemporary schedules. Management of the cooperating redwood mill is currently considering installation of a 10 to 15 M bd. ft. capacity prefreezer.

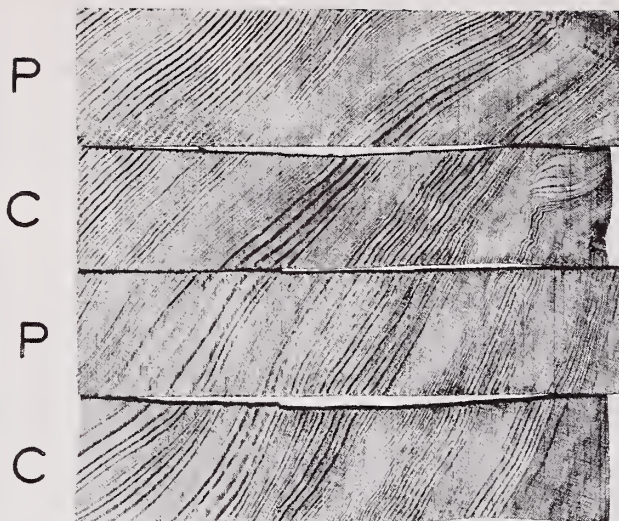


Figure 34. Cross sections at end-of-drying of high-moisture-content redwood boards: P, prefrozen treatment, C, control. Prefreezing greatly reduced shrinkage and eliminated collapse. University of Minnesota 19-56.

Shrinkage in redwood veneer was reduced in both width and thickness. For 1/7" veneer, prefreezing results in a bonus of 3500 sq. ft. for each 1 million sq. ft. of green veneer produced. Prefrozen sheets can be glued-up under standard mill conditions with no difficulty. APA tests are being conducted to evaluate bond quality where veneers were prefrozen.

Interest in prefreezing has been expressed by the pencil slat industry. Investigations are underway on the usefulness of prefreezing in the accelerated drying of incense cedar pencil slats and squares. Prefreezing has reduced the shrinkage of 1" walnut lumber between 10 and 15 percent. Strain patterns, moisture distribution, and effect of growth ring orientation were investigated and the data are being analyzed. Laboratory investigations firmly established the role of water soluble extractives in shrinkage and the effect of prefreezing. It was also found that freezing temperature is an important variable in the application of the prefreezing technique to walnut.

NORTH CAROLINA
State University 4006

Gas phase treatment of wood. Alfred J. Stamm

The progress of this research on the mechanism of movement of gases through wood and their chemical reaction with wood has been accelerated by its involvement in current thesis studies. It was shown that helium gas will distribute throughout the structure of evacuated specimens 18 inches long by 4 inches in diameter to attain 95 percent filling of voids in 20 seconds to about one hour in species ranging from highly permeable to virtually impermeable to liquids. Similar experiments using condensable pentane gas at 85°F. gave almost the same filling.

A preliminary screening study has been made of organic vapors that will react with wood to give it dimensional stability. The most promising vapors found were acetic anhydride and butylisocyanate together with a swelling vapor such as dimethyl formamide. In small specimens, equilibrium swelling was reduced to one third of normal in one to two hours at 265°F. with acetic anhydride. Quite similar results were found with butylisocyanate. These treatments resulted in only a small loss in toughness and abrasion resistance of the wood. Treatments with different vapors that react with wood, and additional studies indicate that sizable specimens can be treated with butylisocyanate. More research will be necessary to determine optimum conditions to attain the most uniform distribution of chemical within the wood.

COLORADO
State University 314

Particle board products from Colorado species.
Harry E. Troxell, Donald L. Crews

This project dealing with particleboard technology of Rocky Mountain species shows substantial progress. Over 150 panels have been carefully produced and laboratory procedures

and production techniques have been evaluated. Density distribution in finished panels was comparable to the density variation in commercial products.

Results of the evaluation of the tensile and static bending properties of Engelmann spruce and lodgepole pine panels show both these properties increasing as density increases and as the length/thickness ratio of the particles increases. The overall data suggest that lodgepole pine makes a stronger board than Engelmann spruce.

A study of springback characteristics of half-inch Engelmann spruce panels has been completed. At low densities, springback was nearly independent of density but increased exponentially above a critical density of about 48 pounds per cubic foot. Bending strengths were impaired drastically by use of pressing times less than four minutes.

NORTH CAROLINA
State University 4017

Problem analysis of pulp and paper mill effluent control and treatment.

Charles N. Rogers, N. Brown

Major pulp and paper manufacturers in the southern states were invited to participate in a problem analysis survey. A positive response from 51 mills indicated the interest of the industry in such a survey. A questionnaire is now in preparation and the assistance of the National Council for Stream Improvement has been offered in pursuing this work.

A study has been initiated with the assistance of the Water Pollution Control Board and of a paper company to determine if wood chips stored at paper mills prior to pulping can be pre-used as a filter medium to remove pulping chemicals, dissolved extractives, and wood components from spent kraft pulping liquor. Preliminary tests indicate that the pH of the liquor can be readily reduced from about 10 down to 5 to 7. Reduction of the spent

liquor in total solids, biological oxygen demand, and color will also be determined. It is hoped that those characteristics will be improved to the point that discharge into streams will not create a pollution hazard.

Additional studies include an examination of the possibilities of decolorizing kraft pulp mill effluent by enzymatic means and the application of linear programming to provide a model for decisions on alternative routing and liquid effluent through available treatment processes.

Auburn University
ALABAMA 902

Evaluation of wood as a light aggregate in concrete products.

Evangelos J. Biblis

This study was initiated to identify those components of southern woods that influence the rate of cure of Portland cement and then to remove or neutralize what proved to be deleterious components. Additional objectives were to relate wood particle geometry to performance of the wood-concrete products and to evaluate durability in wood-concrete products.

For the southern pines, sugar and other hot water extractives extended the setting time of sawdust-cement mixtures. Hot water extraction of sawdust removed sugars and other extractives and served to accelerate setting time of the mixture. Blue-stained sawdust contained less sugar than unstained sawdust, and therefore can accelerate the setting time. Chemical treatment of a sawdust-cement mixture with a 1.0 percent solution of calcium chloride not only accelerated setting time but also equalized the setting time for heartwood and sapwood sawdust. This has important practical significance.

Wood-particle geometry was found to have a negligible effect on the strength of wood-cement mixtures. However, the ratio of wood-particle surface area to weight of cement was an important factor in the strength of a wood-cement mixture.

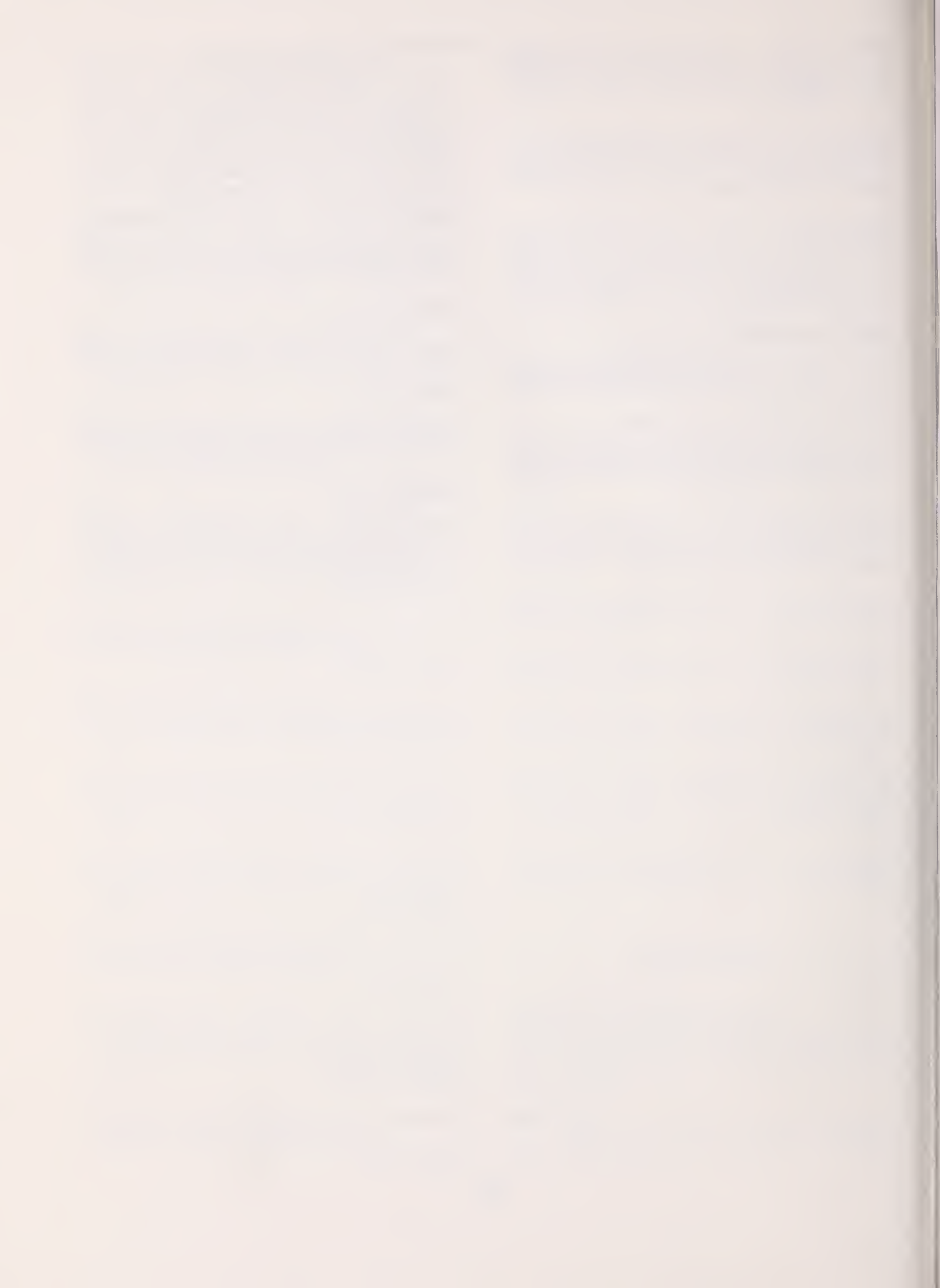
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Ali A. Moslemi.
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SUMMARY OF McINTIRE-STENNIS FORESTRY RESEARCH PROJECT ACTIVITY DURING 1967

University	Soils	Physiology	Ecology	Genetics	Fire	Pathology	Entomology	Silviculture	Timber Mgt.	Recreation	Wildlife	Range	Watershed	Multiple Use	Econ. & Mtg.	Logging	Wood Science	Products	Total No. of Projects	Graduate Students	Publications and Theses
Ala.-Auburn U.	-	1	-	1	-	1	-	1	1	-	-	-	-	-	-	-	3	2	10	8	3
Alaska, U.of	3	1	2	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	7	1	1
Arizona, U.of	-	-	1	-	-	1	-	-	-	1	-	-	1	-	-	-	-	-	4	5	0
Arizona, No.,U.	-	-	1	-	-	-	-	-	1	-	-	1	-	-	-	-	1	-	4	2	0
Arkansas, U.of	-	-	-	-	-	1	3	-	-	-	-	-	-	1	-	-	-	-	5	7	3
California, U.of	-	-	1	-	1	2	-	-	4	-	-	-	-	-	4	-	1	2	15	28	6
Cal.-Humboldt St.Col.	1	-	-	-	-	-	-	-	1	1	1	-	2	-	-	-	-	-	6	3	1
Colorado St.U.	-	-	1	1	1	-	-	-	1	1	-	-	1	-	-	-	-	1	7	8	3
Connecticut, U.of	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-	-	-	3	2	0
Conn. Ag. Ex. Sta.	2	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1	1
Delaware, U.of	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	2	3	3
Florida, U.of	1	1	-	3	-	-	-	-	1	-	1	-	-	-	-	-	-	-	7	2	2
Georgia, U.of	-	2	-	-	-	-	1	2	3	-	3	-	-	-	-	-	2	1	14	15	15
Hawaii, U.of	2	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	3	2	0
Idaho, U.of	-	1	-	1	-	1	1	-	-	1	2	1	-	-	1	-	2	-	11	11	6
Illinois, U.of	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	1	4	4	2
Illinois, S.,U.	-	-	1	-	-	-	-	2	-	4	1	-	-	-	2	-	-	1	11	9	2
Ind.-Purdue U.	-	-	1	-	-	-	-	1	3	-	-	-	-	1	-	-	-	2	8	6	2
Iowa St.U.	-	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1	2	5	7	5
Kansas St.U.	-	-	-	-	-	-	1	3	-	-	-	-	-	-	1	-	-	-	5	4	2
Kentucky, U.of	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	4	2	2
Louisiana St.U.	1	-	-	-	-	-	-	1	1	2	2	-	-	-	1	-	-	-	8	11	7
La. Polytech. Inst.	1	-	-	-	1	1	-	-	1	-	-	-	-	-	-	-	1	-	5	1	1
Maine, U.of	1	1	-	-	-	-	2	-	-	-	1	-	-	-	-	-	2	-	7	6	6
Maryland, U.of	-	1	-	-	-	1	1	-	-	1	-	-	-	-	1	-	-	-	5	7	2
Massachusetts, U.of	-	-	-	-	-	3	-	-	-	-	1	-	1	-	-	-	2	-	7	12	4
Michigan, U.of	-	3	-	1	-	1	2	-	-	1	-	-	-	-	-	-	1	-	9	9	6
Michigan St.U.	-	1	-	1	-	-	1	1	1	-	1	-	-	-	1	-	-	-	7	18	6
Michigan Tech. U.	-	-	-	1	-	-	1	1	1	1	1	-	-	-	-	-	-	-	6	3	3
Minnesota, U.of	-	-	-	1	-	2	-	1	2	2	1	-	-	-	1	-	-	2	12	18	9
Mississippi St.U.	-	2	-	-	-	-	1	-	1	-	-	-	-	-	1	-	2	2	9	2	2
Missouri, U.of	-	2	-	2	-	1	-	-	-	-	-	-	-	-	2	-	1	-	8	12	0
Montana, U.of	1	1	2	1	1	-	1	-	-	1	-	1	-	1	1	-	1	-	12	5	3
Nebraska, U.of	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	2	0
Nevada, U.of	-	1	-	-	-	-	-	2	-	-	-	-	-	1	-	-	-	-	4	2	0
New Hampshire, U.of	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1	-	2	-	5	3	0
N.J.-Rutgers U.	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	2	2	0
New Mexico State U.	-	-	-	-	-	-	1	-	2	-	1	1	-	-	-	-	1	-	6	5	1
New York-Cornell U.	1	-	-	-	-	1	-	-	-	1	1	-	-	-	1	-	-	-	5	5	2
N.Y.-St.Col.of For.	-	3	-	1	-	-	-	-	1	1	1	-	-	-	-	-	2	-	9	8	7
North Carolina St.U.	1	2	-	3	-	1	-	2	1	-	-	-	-	-	1	-	2	5	18	23	9
North Dakota St.U.	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	3	1
Ohio St. U.	1	2	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	5	2	3
Oklahoma St.U.	1	1	-	4	-	1	1	1	3	-	-	-	-	-	-	-	1	-	13	13	2
Oregon St.U.	-	2	2	3	-	1	1	1	2	-	-	-	-	-	-	-	4	1	17	13	8
Pennsylvania St.U.	1	-	-	-	-	2	-	1	1	-	-	-	1	1	1	-	1	1	10	17	9
Puerto Rico, U.of	-	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	-	-	3	0	0
Rhode Island, U.of	-	-	-	-	-	-	-	-	-	-	1	-	1	1	-	-	-	-	3	5	2
S.C.-Clemson U.	1	2	-	3	-	-	-	1	1	-	-	-	-	-	-	1	-	-	9	1	0
South Dakota St.U.	1	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	3	0	0
Tennessee, U.of	1	-	-	-	-	1	-	2	1	1	2	-	-	-	-	-	1	-	9	6	1
Texas A&M U.	-	1	-	-	-	1	1	-	-	-	-	-	-	-	1	-	1	-	5	9	4
Utah St.U.	-	-	-	-	-	-	-	1	1	3	-	1	2	-	-	-	-	-	8	5	1
Vermont, U.of	-	2	-	-	-	-	1	3	2	-	1	-	-	1	2	-	-	-	12	2	5
Virginia Poly.Inst.	-	-	-	-	-	-	-	-	2	-	2	-	-	-	2	-	-	1	7	15	9
Washington, U.of	2	2	-	2	1	1	2	-	-	1	-	-	-	-	1	1	5	2	20	15	3
Washington St.U.	1	-	-	1	-	1	-	1	-	1	-	-	1	-	-	-	2	-	8	1	2
West Virginia, U.of	-	-	-	1	-	-	-	-	1	-	-	-	-	-	-	-	1	2	5	11	1
Wisconsin, U.of	-	1	-	1	-	2	1	-	-	-	-	-	-	-	2	-	-	1	8	2	13
Wyoming, U.of	-	-	-	1	-	1	-	-	-	-	-	2	-	-	-	-	-	-	4	4	1
Totals for all 60 Universities	25	42	14	34	5	30	27	34	40	25	27	7	10	8	30	2	43	32	435	408	192

